

THEORY AND TESTING OF DUPLEXERS



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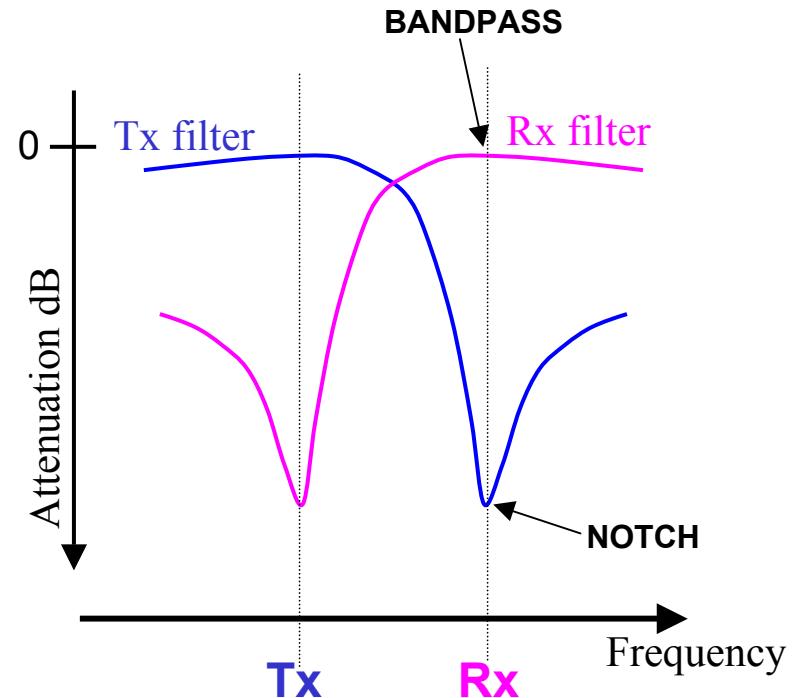
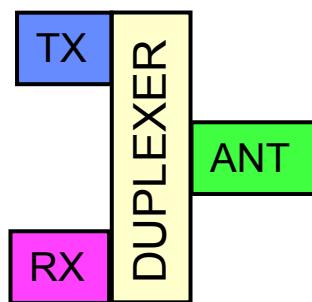
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- ❑ INTRO
- ❑ WHY USE DUPLEXERS ?
- ❑ BASIC TYPES OF DUPLEXERS
- ❑ SIMPLE LC MODELS FOR EACH TYPE
- ❑ ADJUSTMENT AND VERIFICATION
- ❑ PUTTING IT ALL TOGETHER - EXAMPLES
- ❑ PITFALLS
- ❑ REFERENCES

WHY USE DUPLEXERS ?

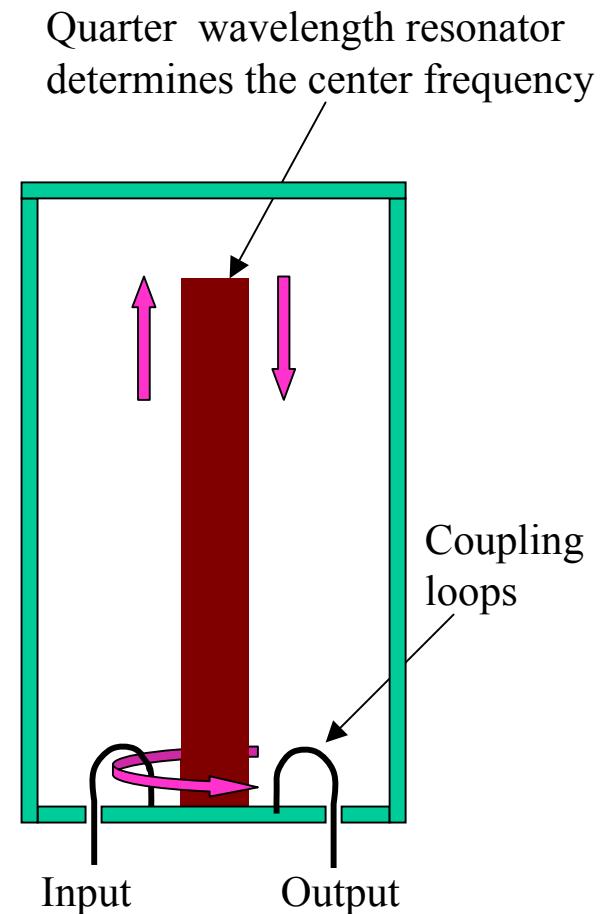
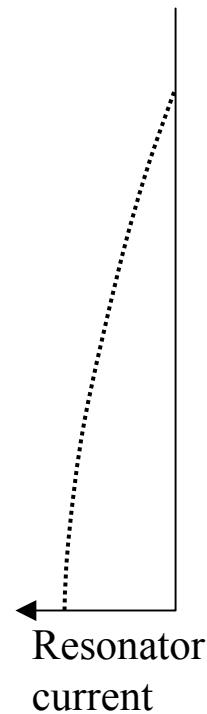
DUPLEXERS...

- ❑ Allow simultaneous transmit and receive on the same antenna
- ❑ The Rx filter attenuates the TX signal ~ 75 dB or more (approx 30 million times) and vice-versa
- ❑ The Tx filter attenuates the TX broadband noise being fed into the Rx by a similar amount
- ❑ Three port devices:



CAVITIES IN GENERAL

- ❑ Use a very low loss transmission line to improve selectivity (high Q)
(~0.08 dB loss / 100 ft for a 6 in. cavity @ 150 MHz)
- ❑ The resonator acts as a quarter wave antenna inside a closed box, with max. current at the base
- ❑ In – out loops magnetically couple energy to the resonator
- ❑ Capacitive coupling may also be used but not discussed here



LOOP COUPLING TO THE RESONATOR

- Loop orientation affects coupling:



- Loop size: increasing the loop size increases coupling and its inductance as well
- Loop proximity from the resonator: placing the loop closer will increase coupling.
- Loop coupling affects the insertion loss and selectivity in the bandpass region and the notch frequency in notch-bandpass designs.

BASIC TYPES OF DUPLEXERS

TX – RX FREQ SEPARATION

LO – HI PASS FILTERS

WIDE

 BANDPASS CAVITIES

MEDIUM

NOTCH – BANDPASS CAVITIES

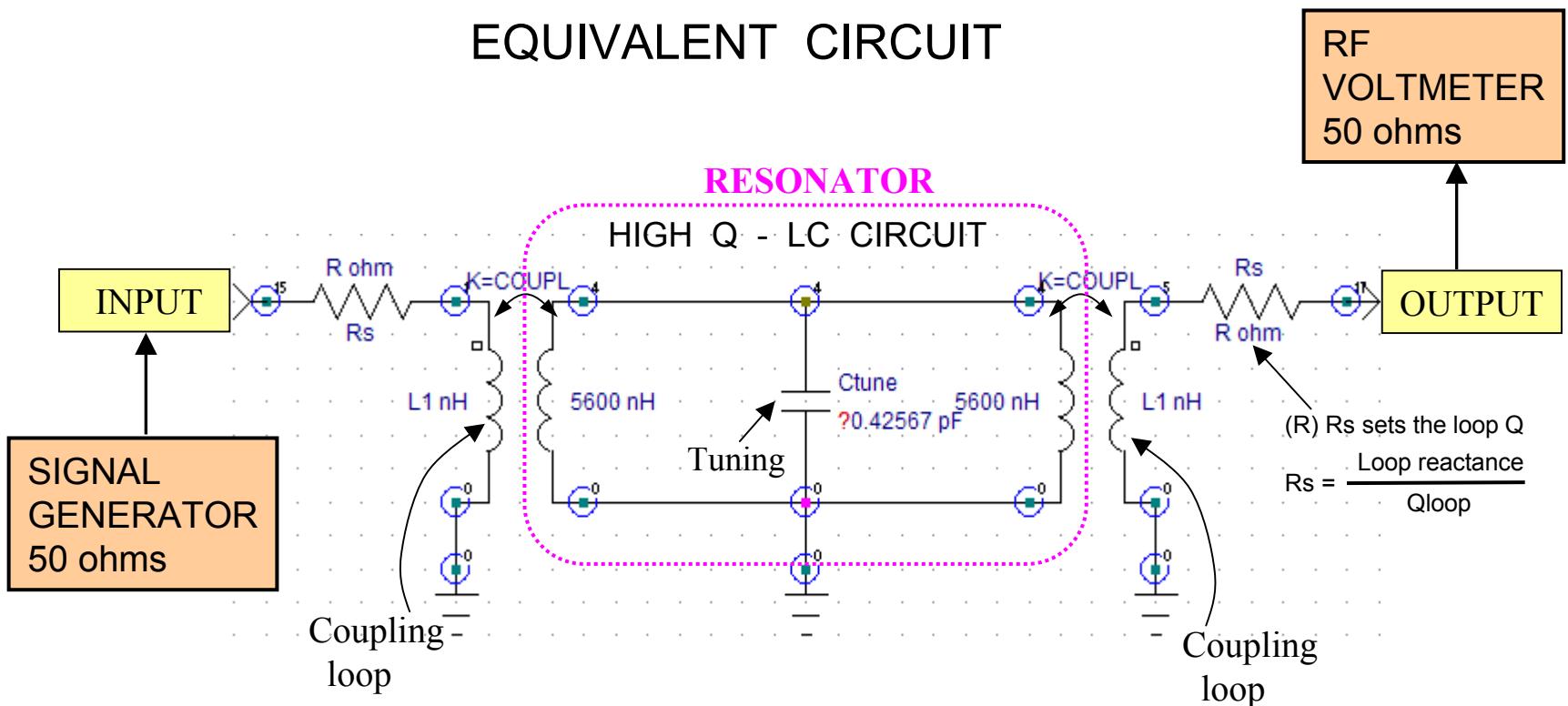
NARROW

NOTCH CAVITIES

NARROW

BANDPASS CAVITIES

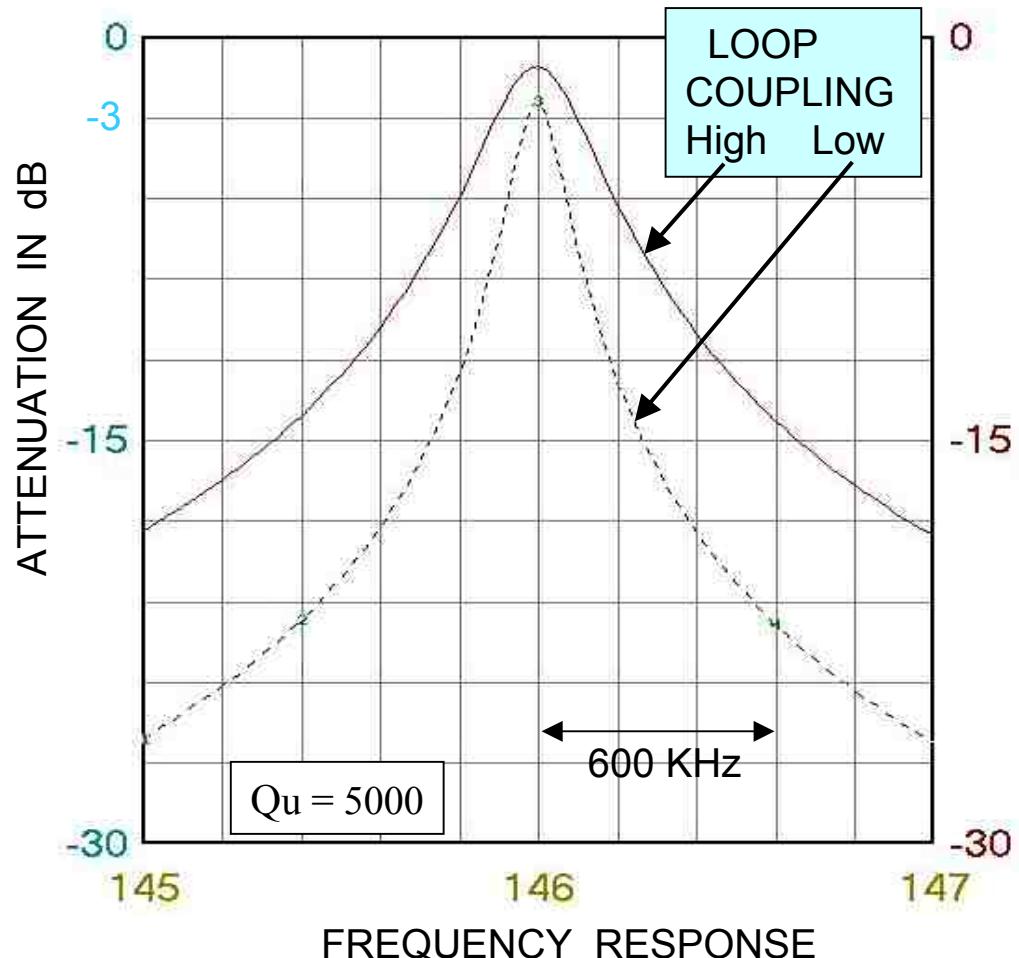
EQUIVALENT CIRCUIT



- ❑ THE QUARTER WAVELENGTH RESONATOR IS MODELED WITH A HIGH Q - LC CIRCUIT (2 x 5600 nH inductors and a capacitor)
- ❑ TYPICAL RESONATOR Qu VALUES: 2100 for 4 in. Cavity, > 5000 for a 6 in. cavity

BANDPASS RESONATOR RESPONSE CURVES

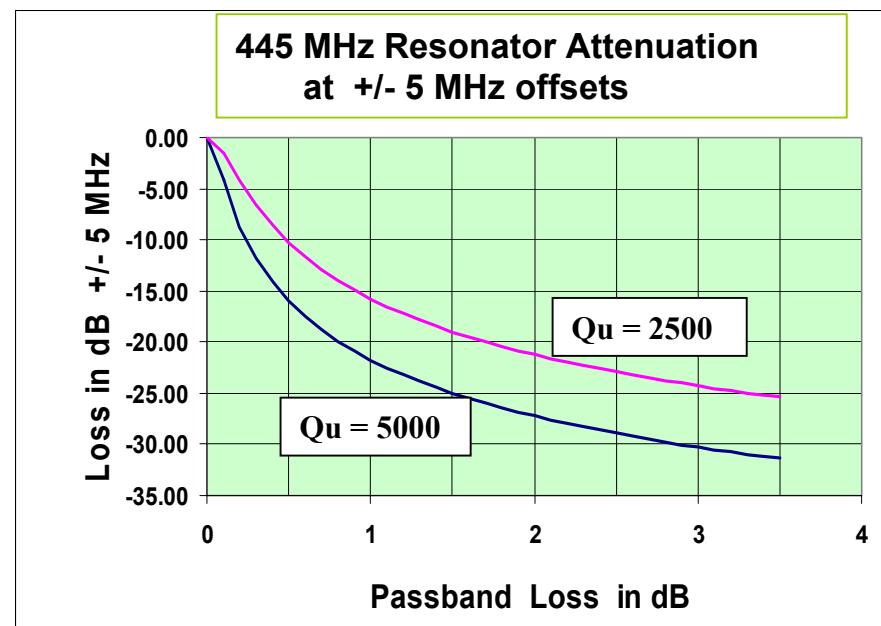
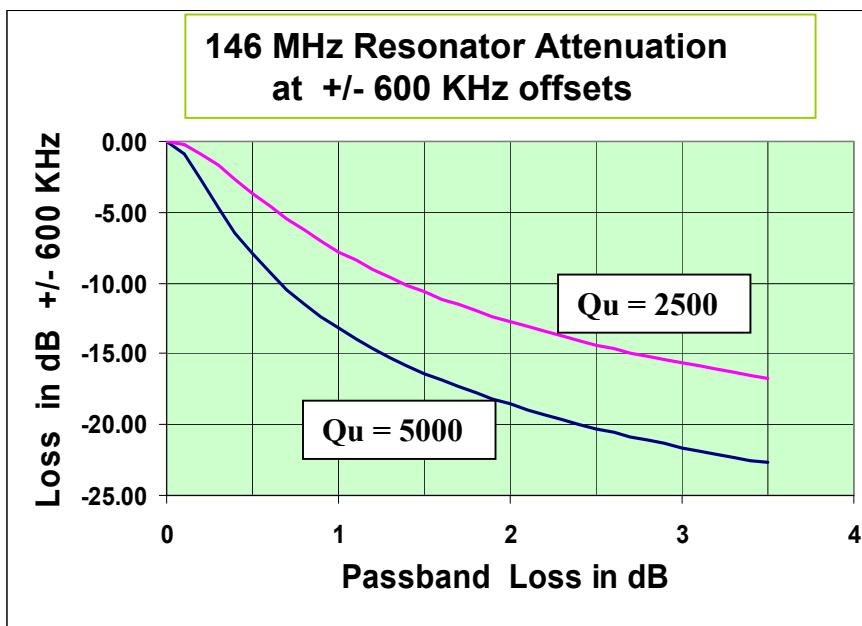
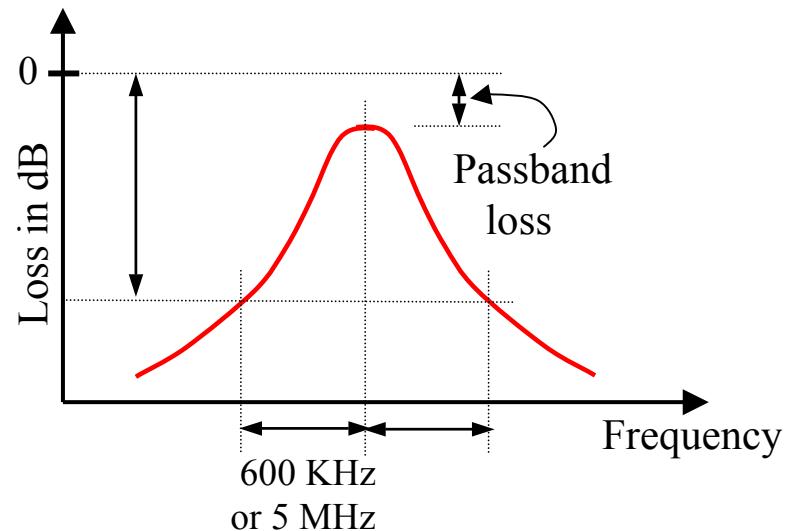
- CHANGING THE COUPLING TRADES BANDPASS LOSS FOR SELECTIVITY
- THE Q_c OF THE COUPLING LOOPS DOES NOT AFFECT THE RESPONSE IF: $Q_c > 100$



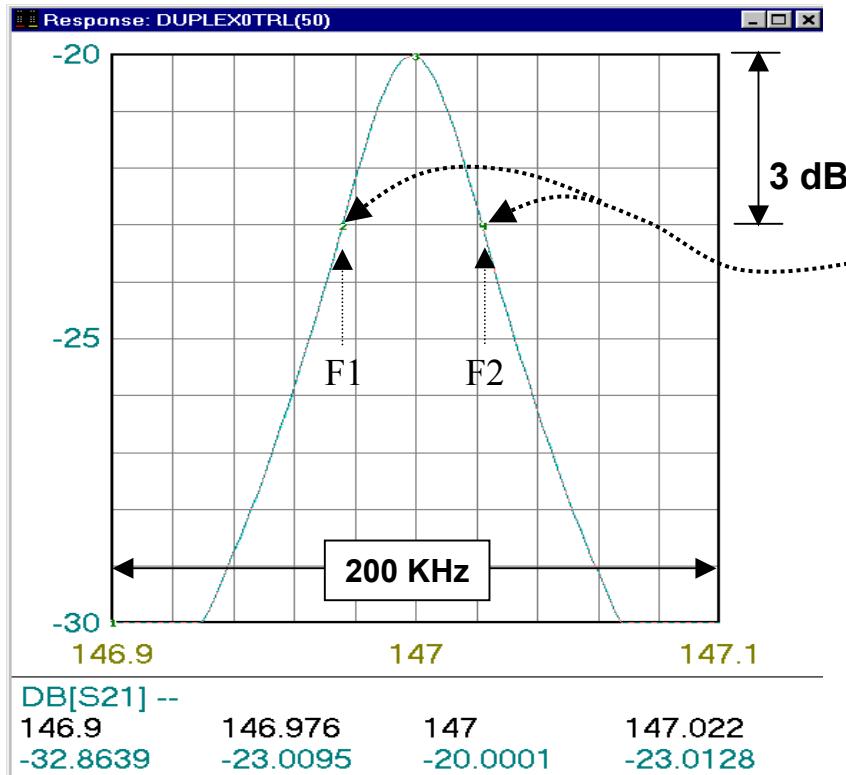
RESONATOR Qu , PASSBAND LOSSES AND SELECTIVITY

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- Qu IS THE QUALITY FACTOR OF THE RESONATOR (unloaded Q)
- Qu INFLUENCES THE PASSBAND LOSSES AND THE ATTENUATION AWAY FROM THE PASSBAND
- ONE MAY TRADE PASSBAND LOSS FOR SELECTIVITY AND VICE-VERSA



MEASURING THE Qu FACTOR (Unloaded Q of the cavity)



- Adjust the coupling loops to obtain ~ 20 dB loss in the passband
- Measure and note the frequencies F1 and F2 (in MHz) that give 3 dB attenuation w/r to the peak:
- Calculate the quality factor Qu:

$$Qu = \frac{0.55 * (F1 + F2)}{(F2 - F1)}$$

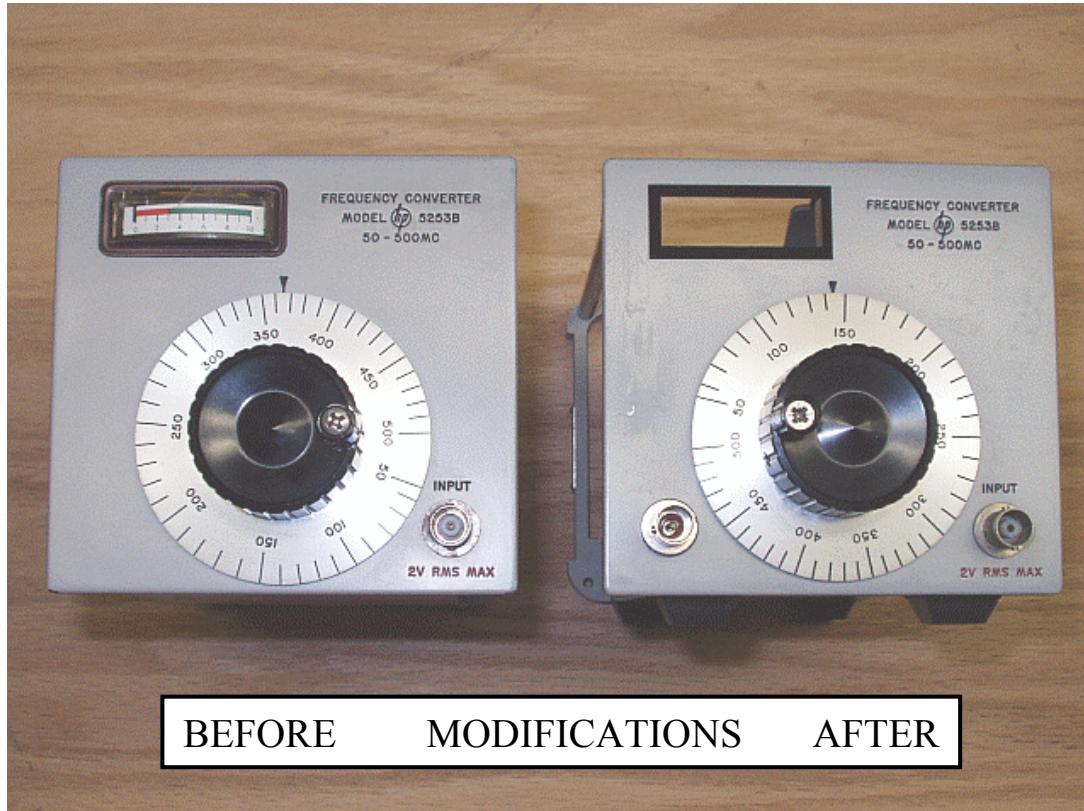
(Use F2 > F1)

A 6 in. VHF cavity should yield Qu > 4000, typically 5000

Measured values on a 6 in. cavity (notch): Q = 4650 (Davicom Technologies Inc model BR-15107)

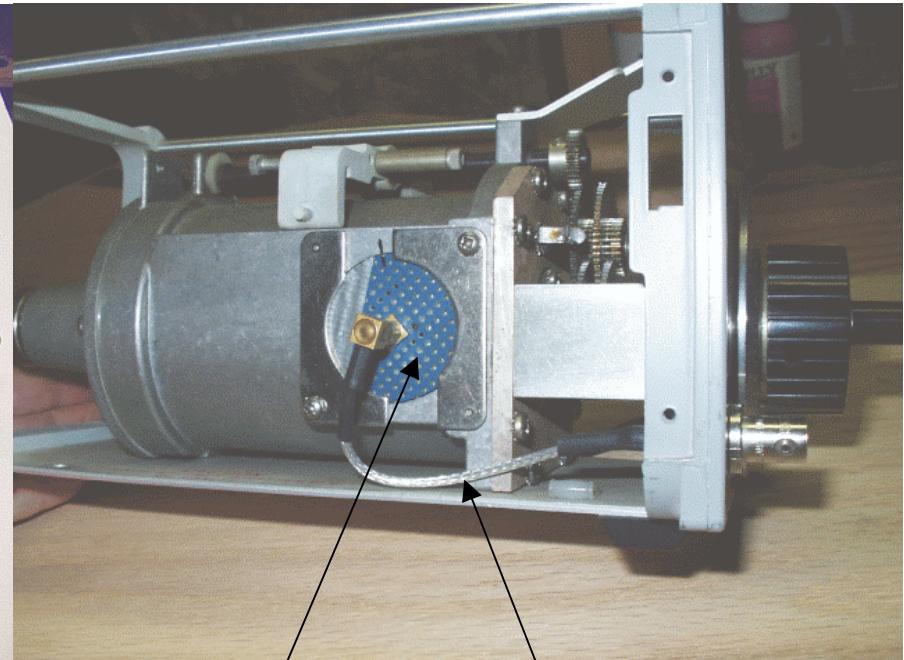
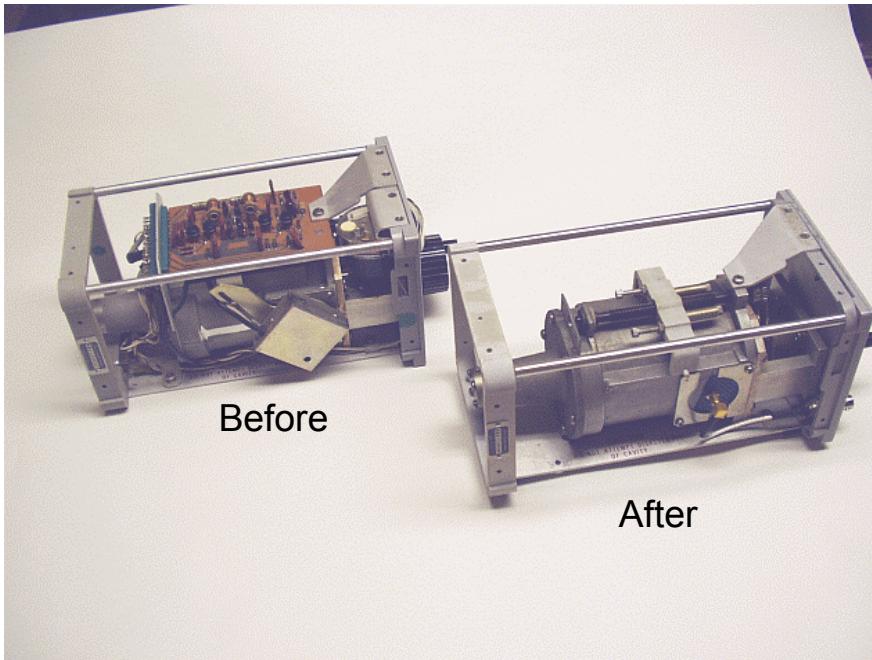
On a 6 in. bandpass cavity: Q = 5675 (Sinclair FP20107*3)

A MINIATURE BANDPASS CAVITY FROM HP



- This is model HP 5253 Plug-in Frequency Converter
- Easily modified to form a bandpass cavity
- Covers 50 - 500 MHz frequency range

A MINIATURE BANDPASS CAVITY FROM HP



Adding the loop and cable
(both sides)

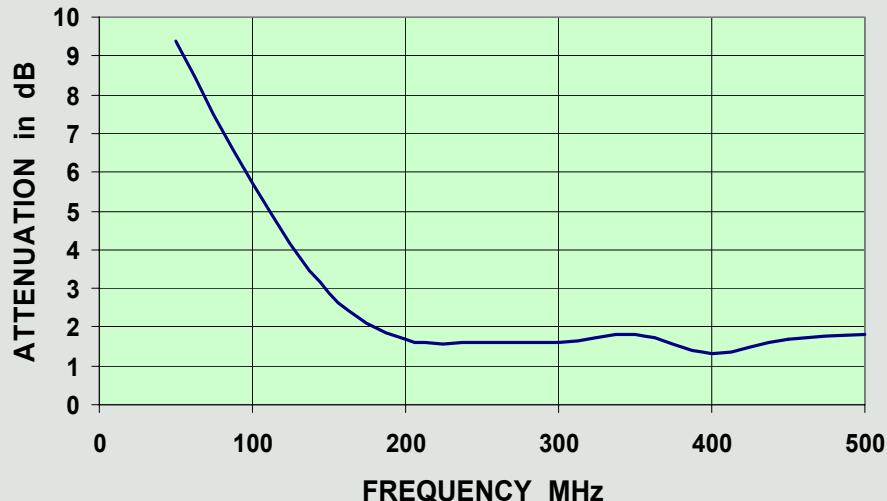
A MINIATURE BANDPASS CAVITY FROM HP

Details of the coupling loop

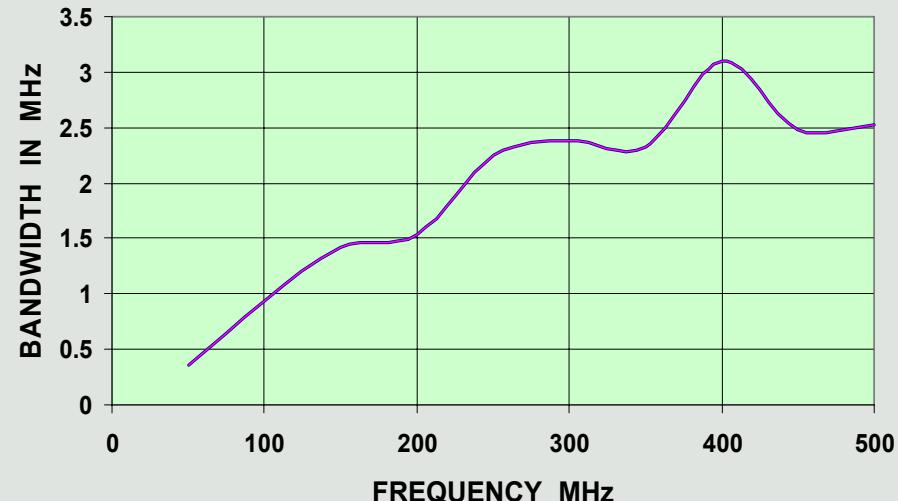
Note: loops are oriented at right angle of each other to minimize direct loop to loop coupling



INSERTION LOSS



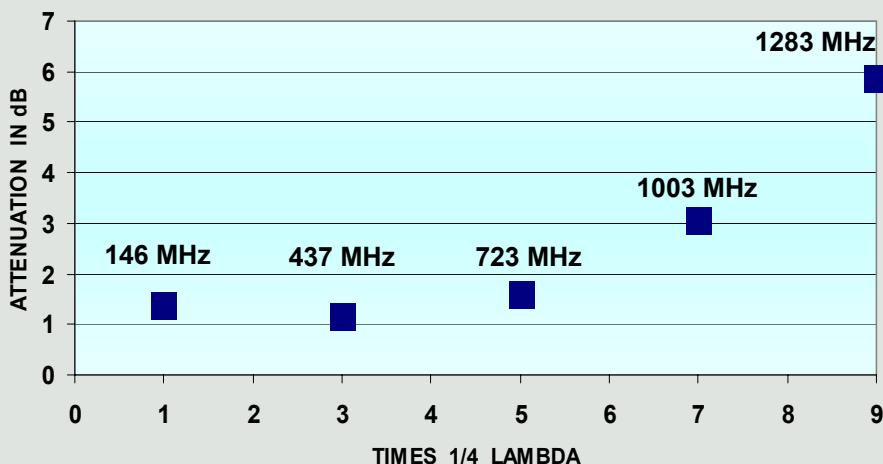
3 dB BANDWIDTH



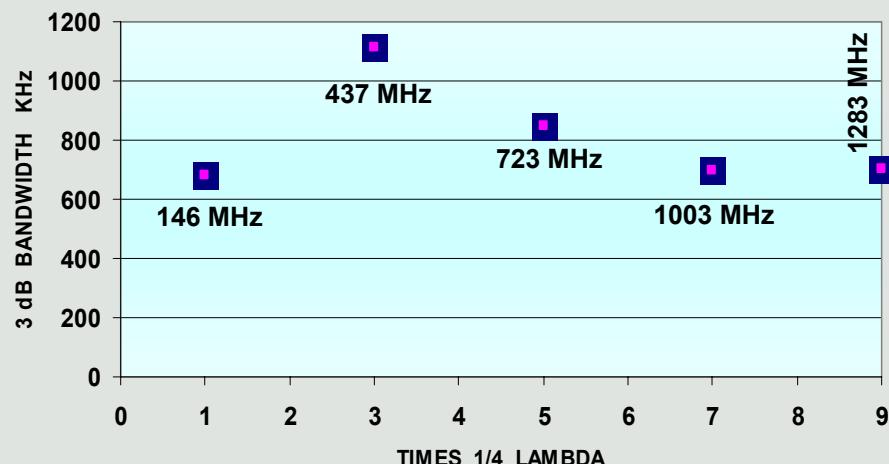
BANDPASS CAVITIES - OVERTONE OPERATION

- CAVITIES WILL OPERATE AT ODD MULTIPLES OF THEIR FUNDAMENTAL FREQUENCY
- OPERATION AT 3X and 5X THE FUNDAMENTAL FREQUENCY PROVIDES LOW LOSSES AND A HIGHER Q_u FACTOR (Q_u IS MULTIPLIED BY 1.7 AT 3X THE FUNDAMENTAL)

4 in. BANDPASS CAVITY
ATTENUATION vs MODE



4 in. BANDPASS CAVITY
3 dB BANDWIDTH vs MODE

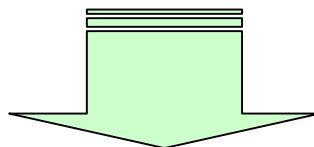


NOTCH – BANDPASS CAVITIES

❑ LO PASS – HI PASS FILTERS

❑ BANDPASS CAVITIES

→ ❑ NOTCH – BANDPASS CAVITIES



→ ❑ DUAL LOOP NOTCH-BANDPASS CAVITIES

❑ SINGLE LOOP SERIES RESONANT NOTCH-BANDPASS

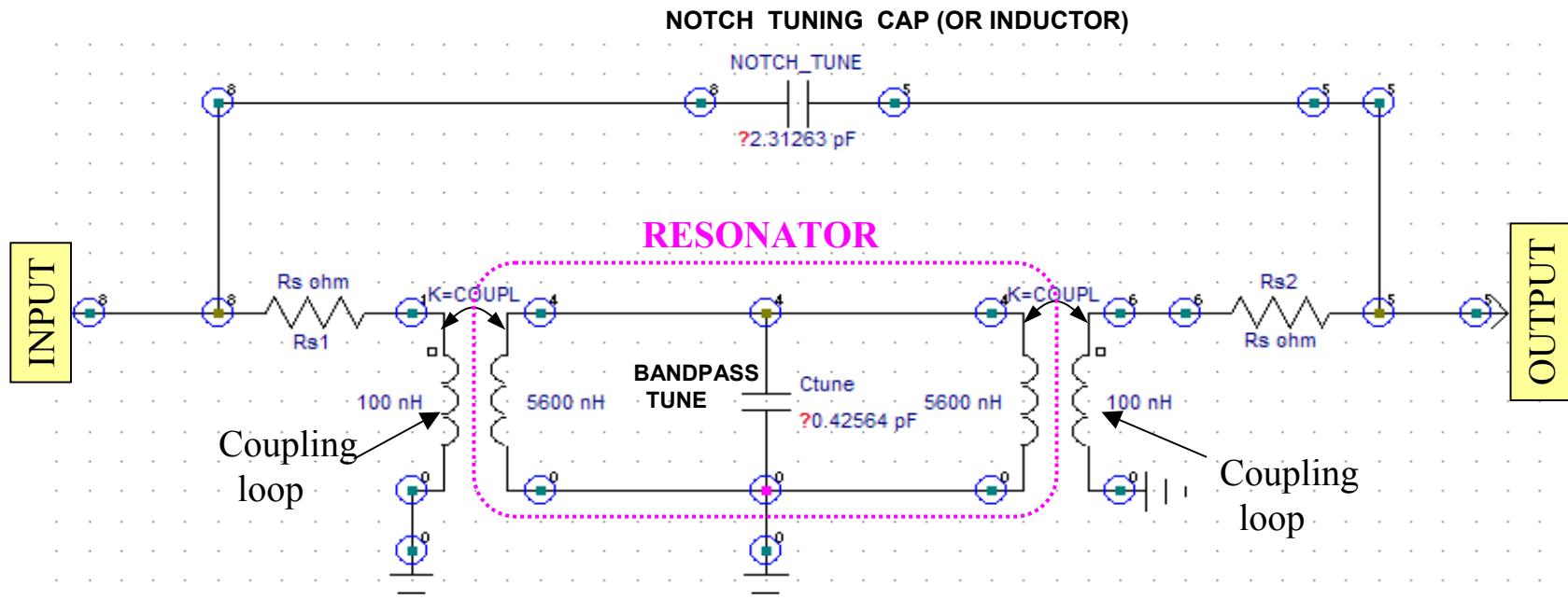
❑ SINGLE LOOP PARALLEL RESONANT NOTCH-BANDPASS (Q circuit)

DUAL LOOP NOTCH-BANDPASS CAVITY



DUAL LOOP NOTCH-BANDPASS (modified bandpass)

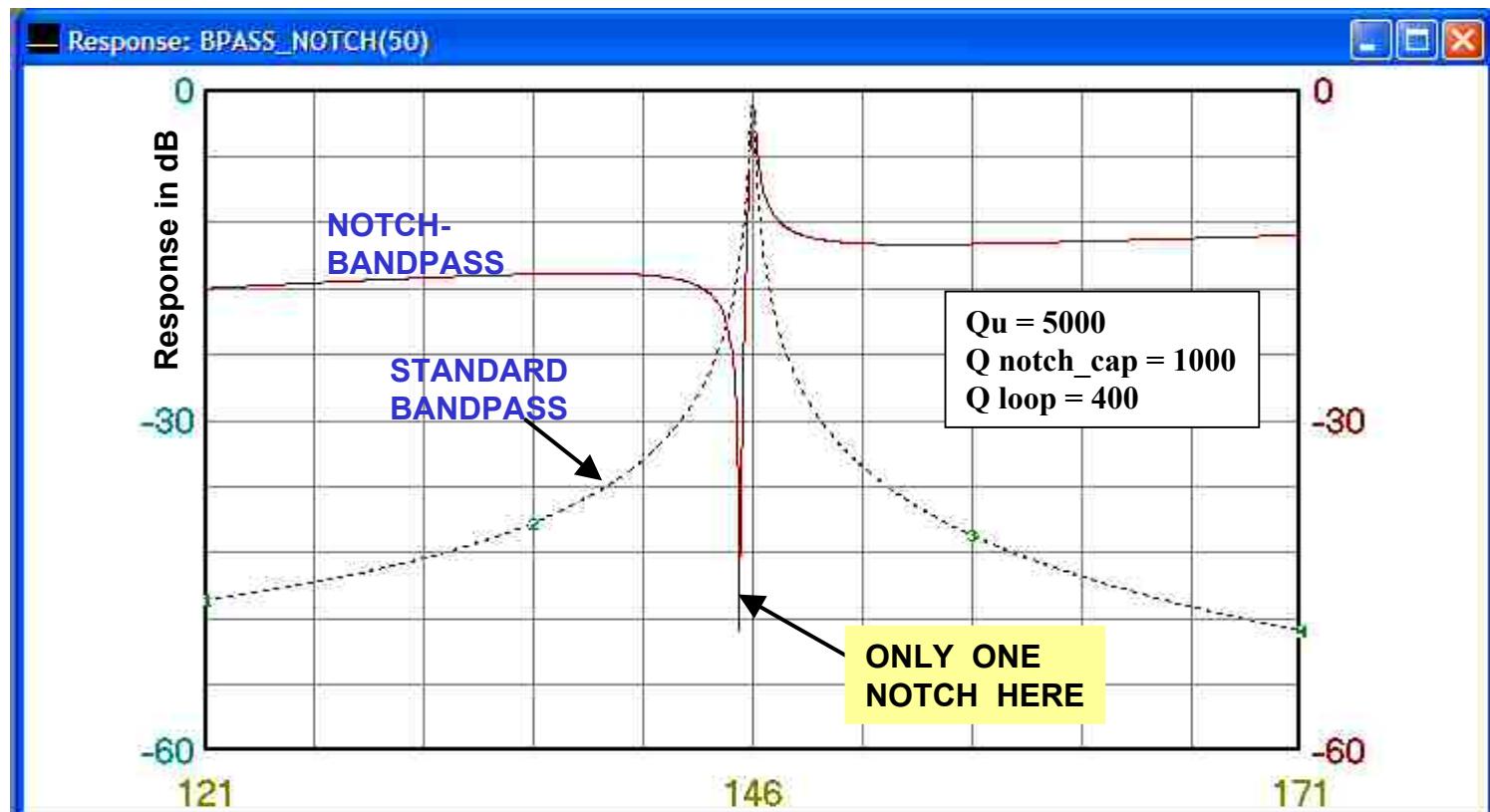
- A LOW VALUE CAPACITOR IS ADDED BETWEEN INPUT AND OUTPUT
- GENERATES A TRANSMISSION NOTCH BELOW THE BANDPASS
- AN INDUCTOR WILL SET THE NOTCH ABOVE THE BANDPASS
- NOTCH TUNING INTERACTS SOMEWHAT WITH CENTER FREQUENCY
- THE CAPACITOR MAY BE REPLACED BY A SERIES L-C THAT CAN GIVE L OR C BEHAVIOUR



EQUIVALENT CIRCUIT

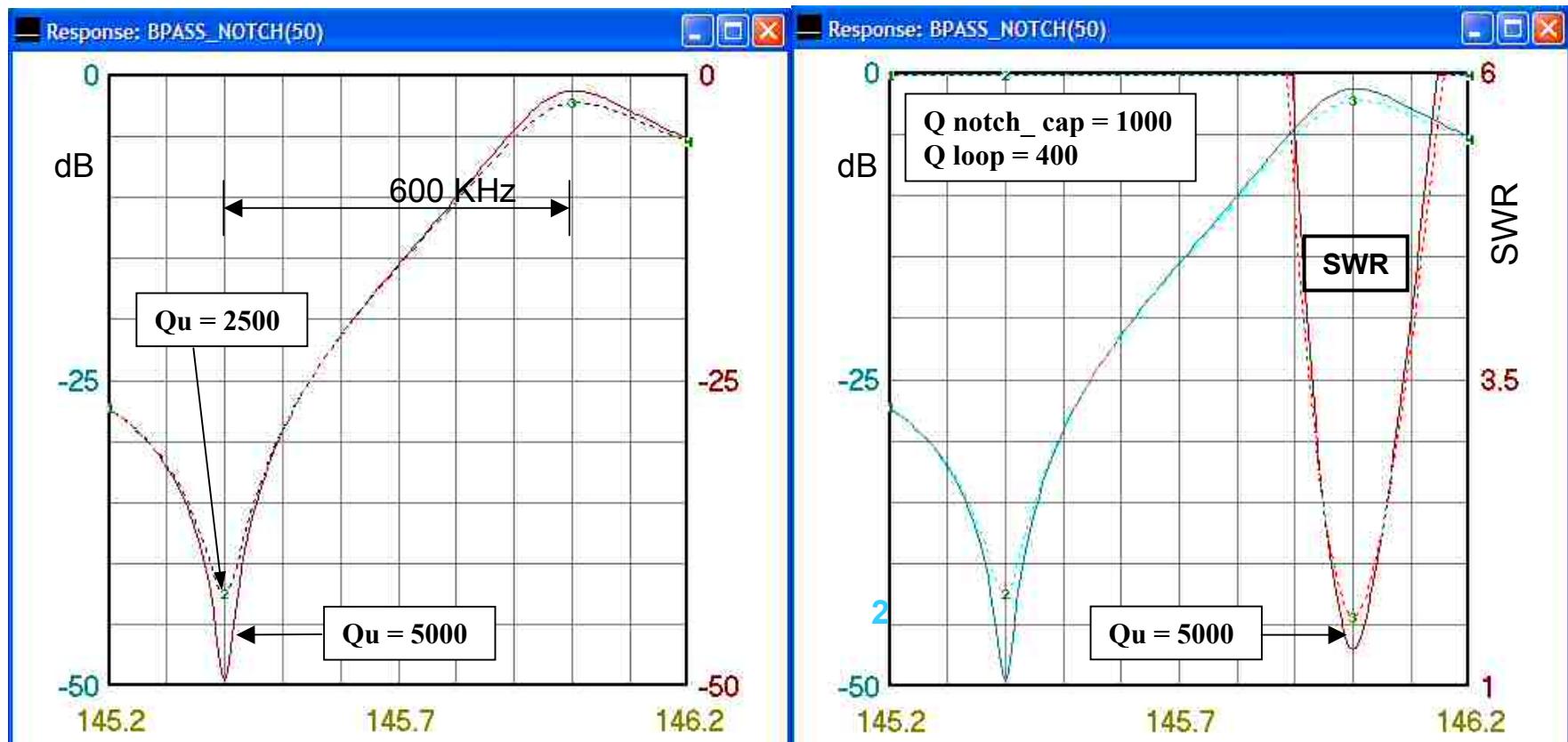
DUAL LOOP NOTCH-BANDPASS (modified bandpass)

- SERIES CAPACITOR BETWEEN INPUT AND OUTPUT (~ 2.3 pF) GIVES THE DESIRED NOTCH-BANDPASS CHARACTERISTIC – ALLOWS NOTCH TUNING
- SERIES CAPACITOR TUNING SENSITIVITY: ~ 16 % PER 100 KHz (146 MHz) (REDUCING C MOVES THE NOTCH UP IN FREQUENCY)
- BANDPASS LOSS ~ UNCHANGED – COMPARED TO STANDARD BANDPASS



DUAL LOOP NOTCH-BANDPASS (modified bandpass)

- REDUCING Q_u FROM 5000 TO 2500 REDUCES THE NOTCH BY ~ 5 dB AND ADDS ~ 1 dB LOSS IN THE BANDPASS
- THE BANDPASS CENTER HAS LOWEST SWR - ALWAYS

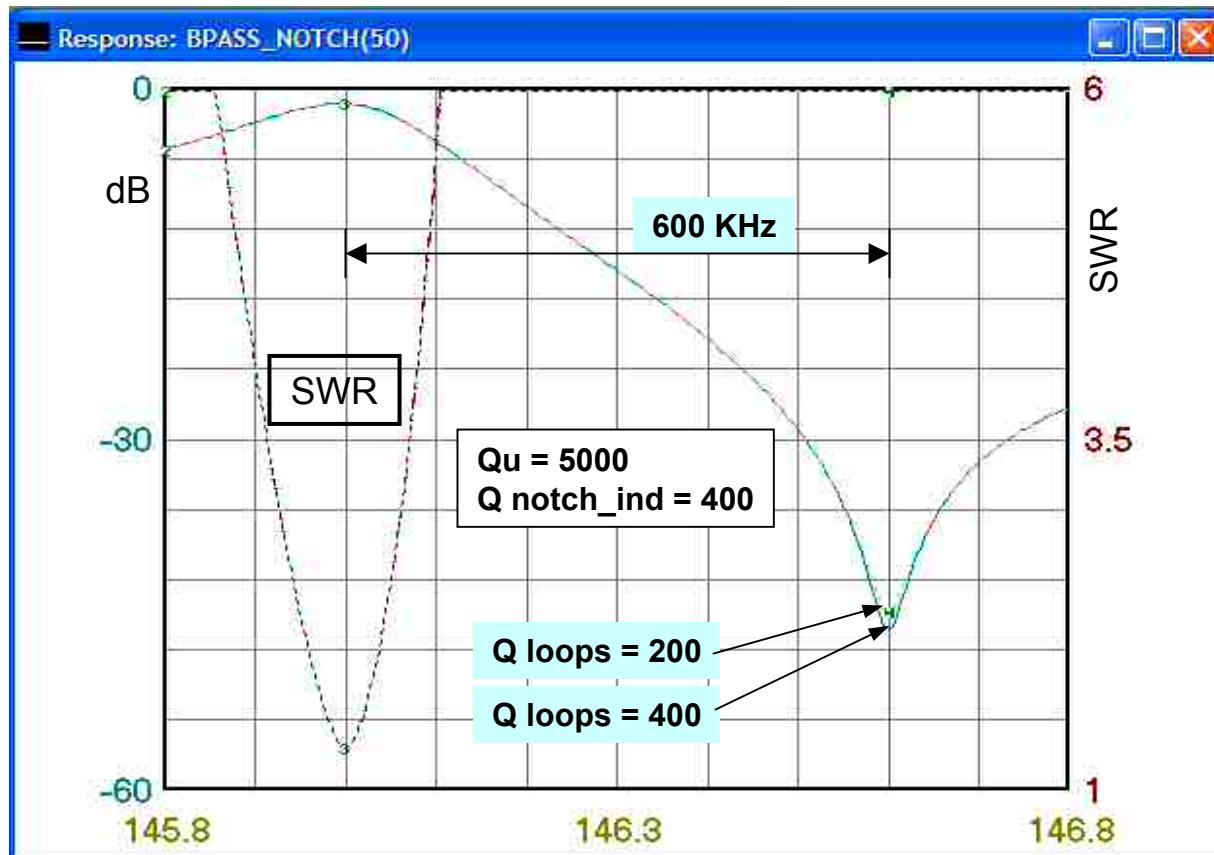


EFFECT OF CAVITY Q (Q_u)

THE SWR CURVE DEFINES THE EXACT BANDPASS FREQUENCY

DUAL LOOP NOTCH-BANDPASS (modified bandpass)

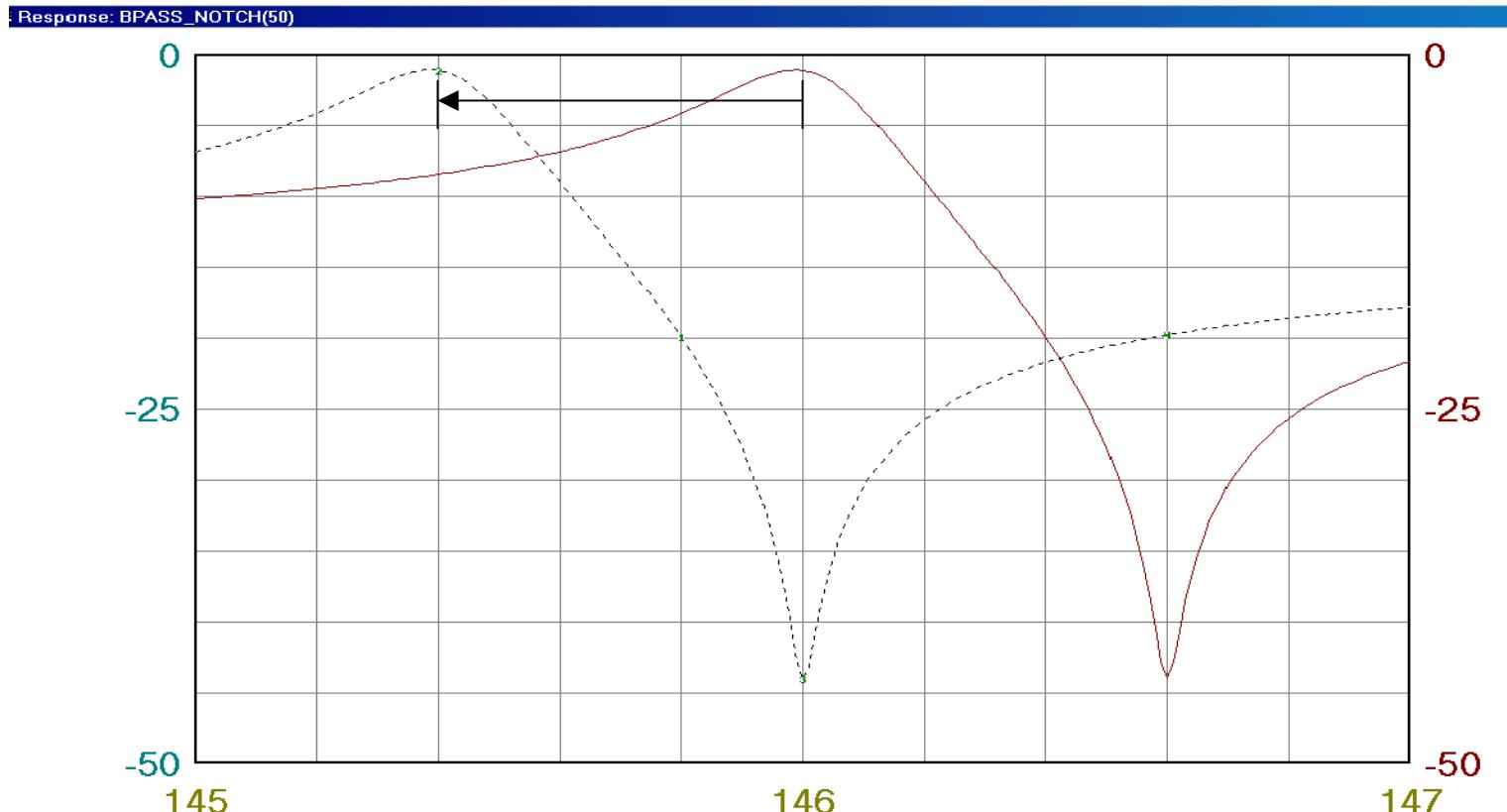
- SETTING THE NOTCH ABOVE THE BANDPASS REQUIRES REPLACING THE SERIES CAP BY A SERIES INDUCTOR (~ 500 nH at 146 MHz)
- REDUCING THE Q FACTOR OF THE LOOPS FROM 400 TO 200 DEGRADES THE NOTCH DEPTH BY ~ 1.5 dB



SETTING THE NOTCH ABOVE THE BANDPASS

DUAL LOOP NOTCH-BANDPASS (modified bandpass)

- INCREASING THE RESONATOR LENGTH MOVES THE BANDPASS FREQUENCY DOWN
- SHIFTING THE BANDPASS FREQUENCY DOWN ALSO SHIFTS THE NOTCH FREQUENCY BY THE SAME AMOUNT

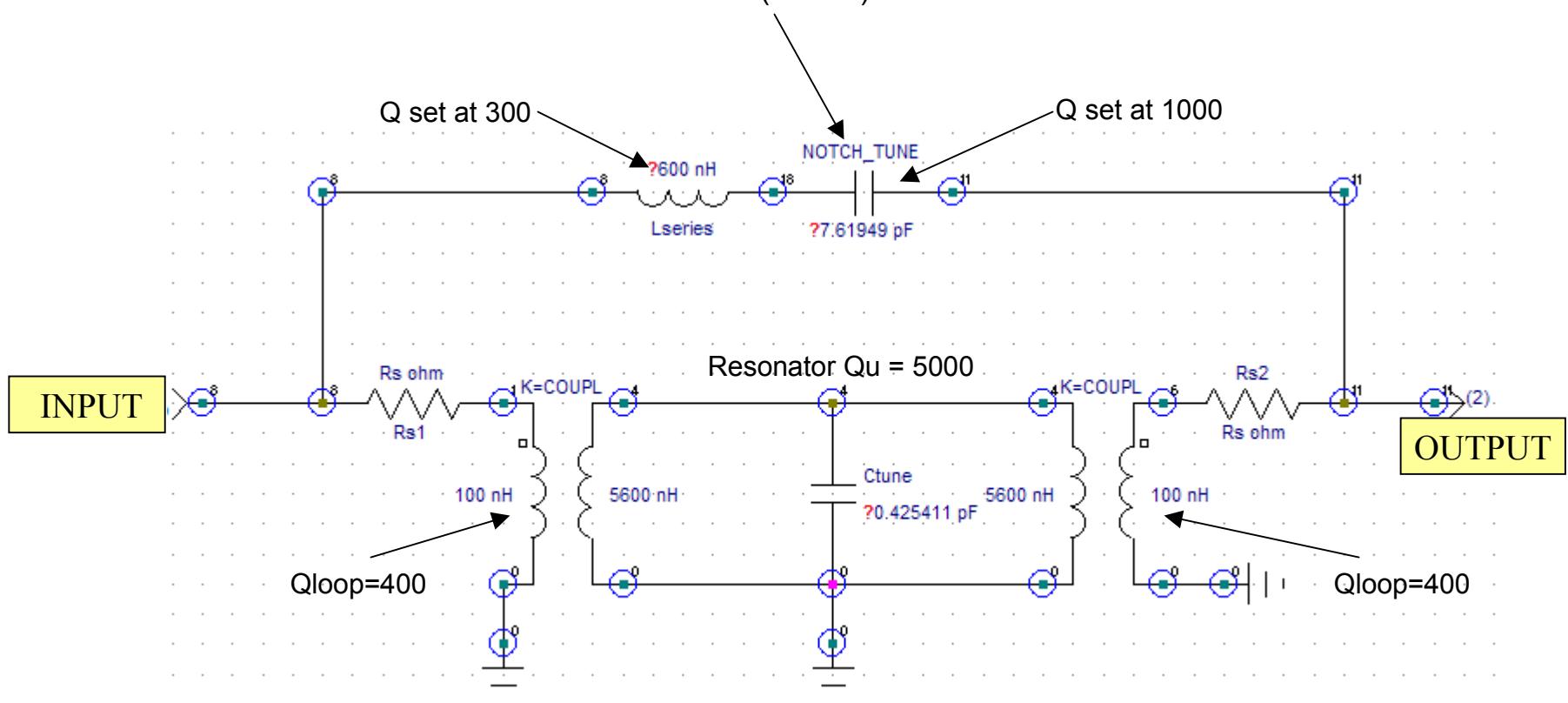


MOVING THE BANDPASS FREQUENCY DOWN MOVES THE NOTCH BY THE SAME AMOUNT 21

DUAL LOOP NOTCH-BANDPASS (modified bandpass)

SERIES L-C BETWEEN INPUT AND OUTPUT

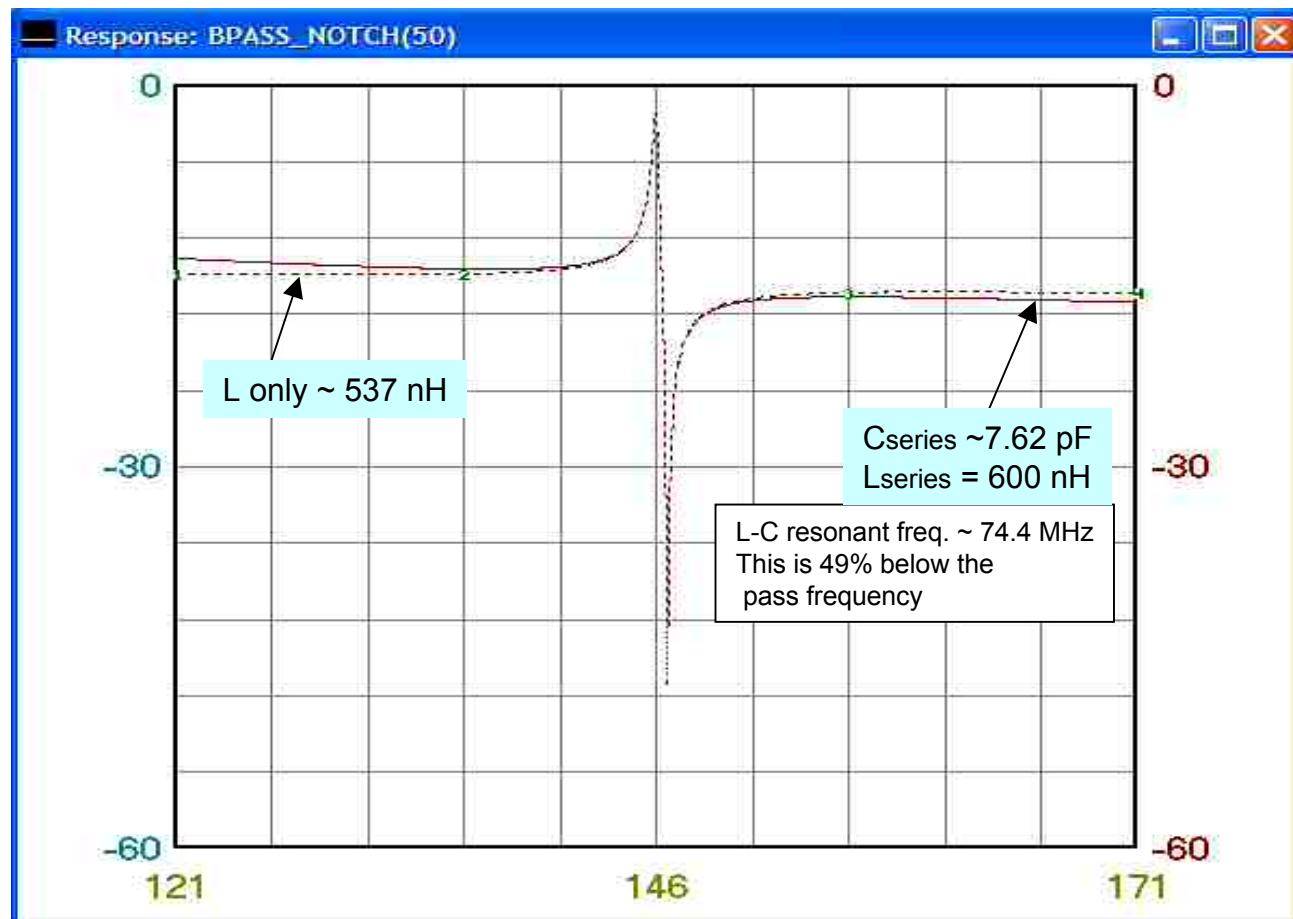
- ALLOWS SETTING THE NOTCH ABOVE AND BELOW THE BANDPASS FREQUENCY BY ADJUSTING THE C ELEMENT ONLY (Cseries)



DUAL LOOP NOTCH-BANDPASS (modified bandpass)

SERIES L-C BETWEEN INPUT AND OUTPUT

NOTCH ON HIGH SIDE

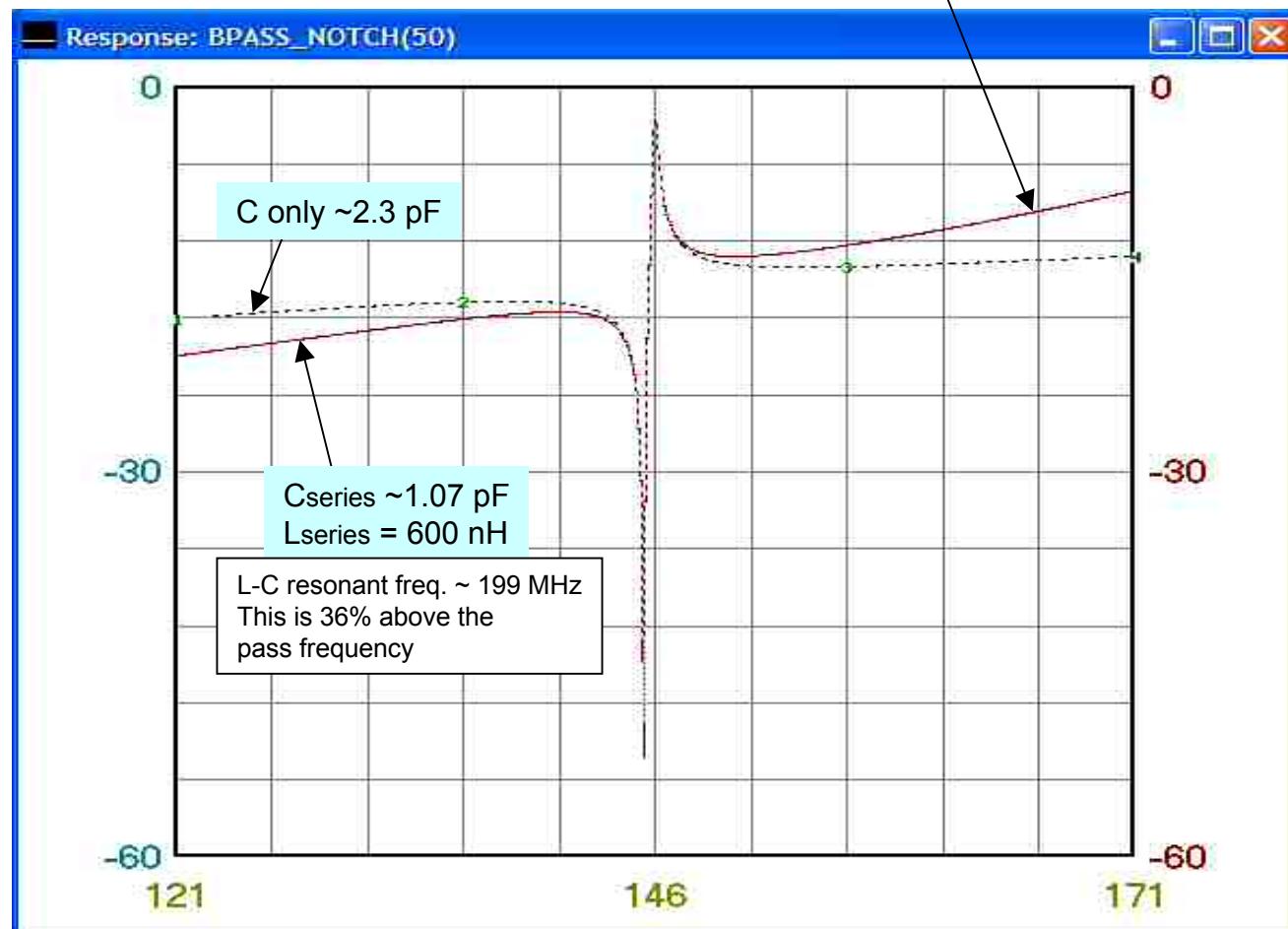


DUAL LOOP NOTCH-BANDPASS (modified bandpass)

SERIES L-C BETWEEN INPUT AND OUTPUT

NOTCH ON LOW SIDE

Note the degradation of the attenuation above the pass frequency



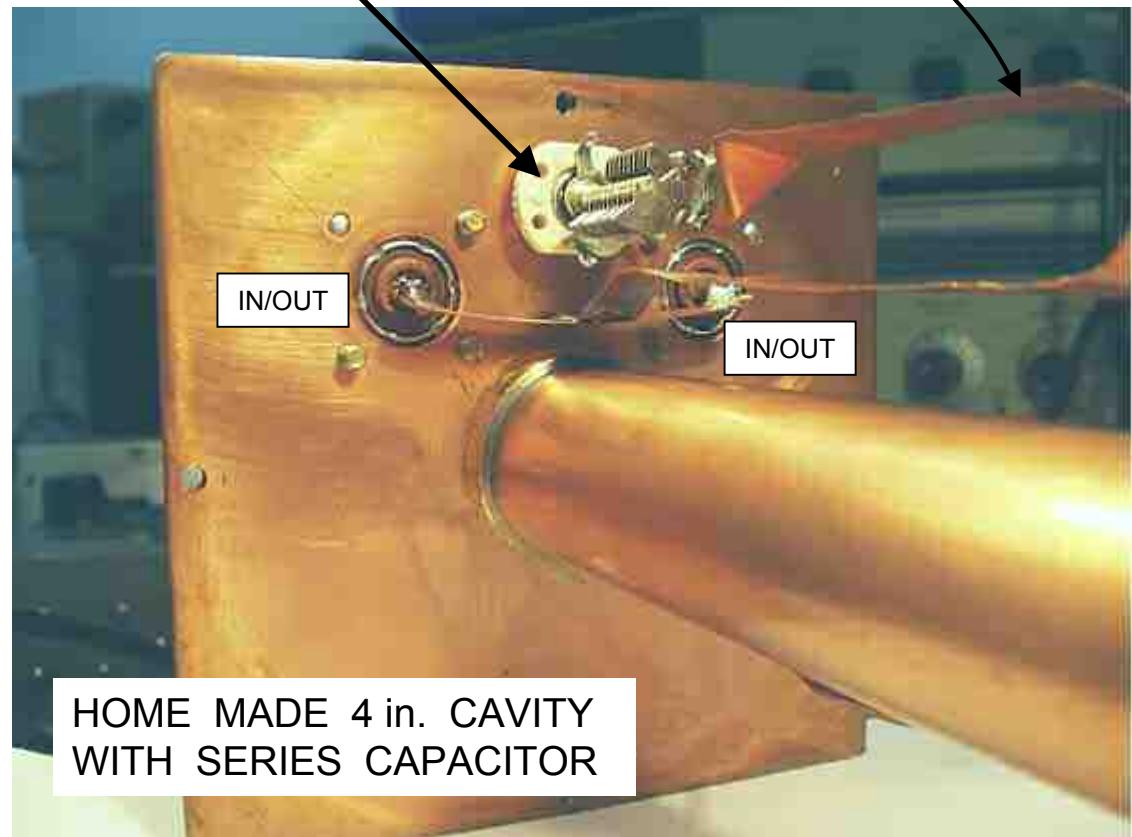
NOTCH – BANDPASS SERIES RESONANT LOOP CAVITIES

- DUAL LOOP NOTCH-BANDPASS CAVITIES
-  SINGLE LOOP SERIES RESONANT NOTCH-BANDPASS
- SINGLE LOOP PARALLEL RESONANT NOTCH-BANDPASS (Q circuit)

SINGLE LOOP SERIES RESONANT NOTCH-BANDPASS

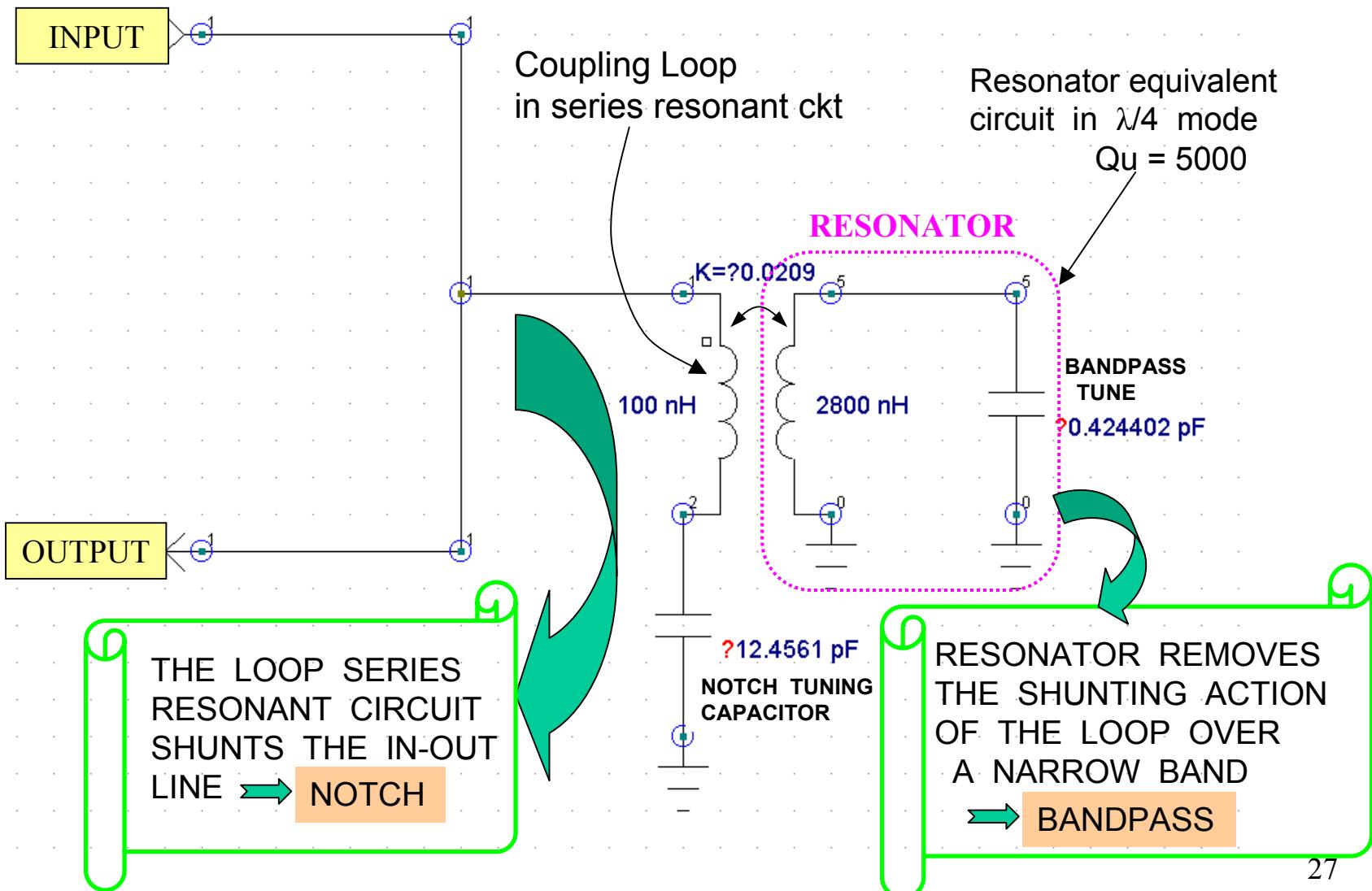
- ONLY ONE LOOP IS USED
- A SERIES CAPACITOR ADJUSTS THE NOTCH FREQUENCY ABOVE AND BELOW THE BANDPASS

A SINGLE CONNECTOR WITH AN EXTERNAL TEE WILL WORK AS WELL



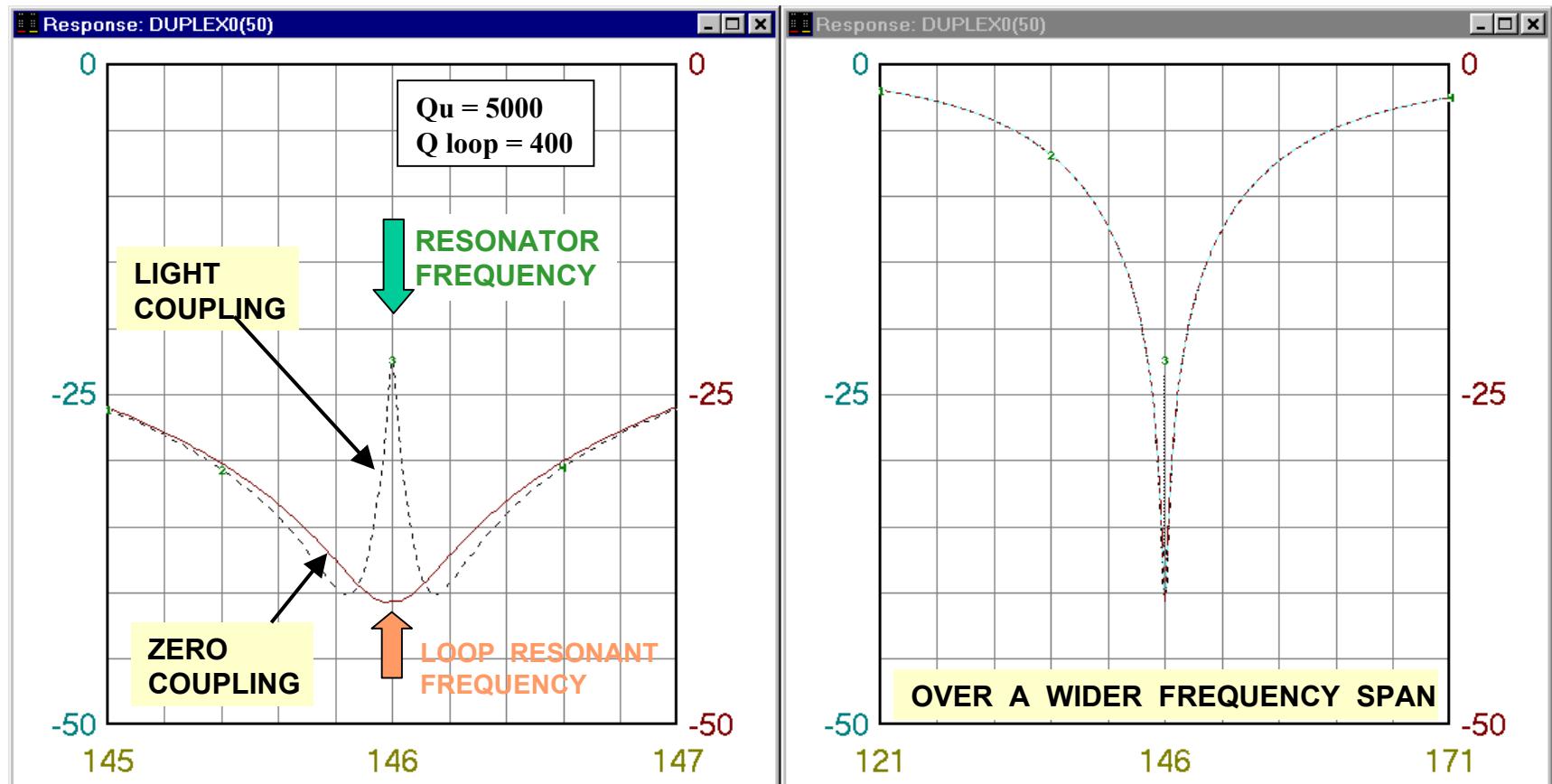
SINGLE LOOP SERIES RESONANT NOTCH-BANDPASS

GIVES NOTCH – BANDPASS RESPONSE



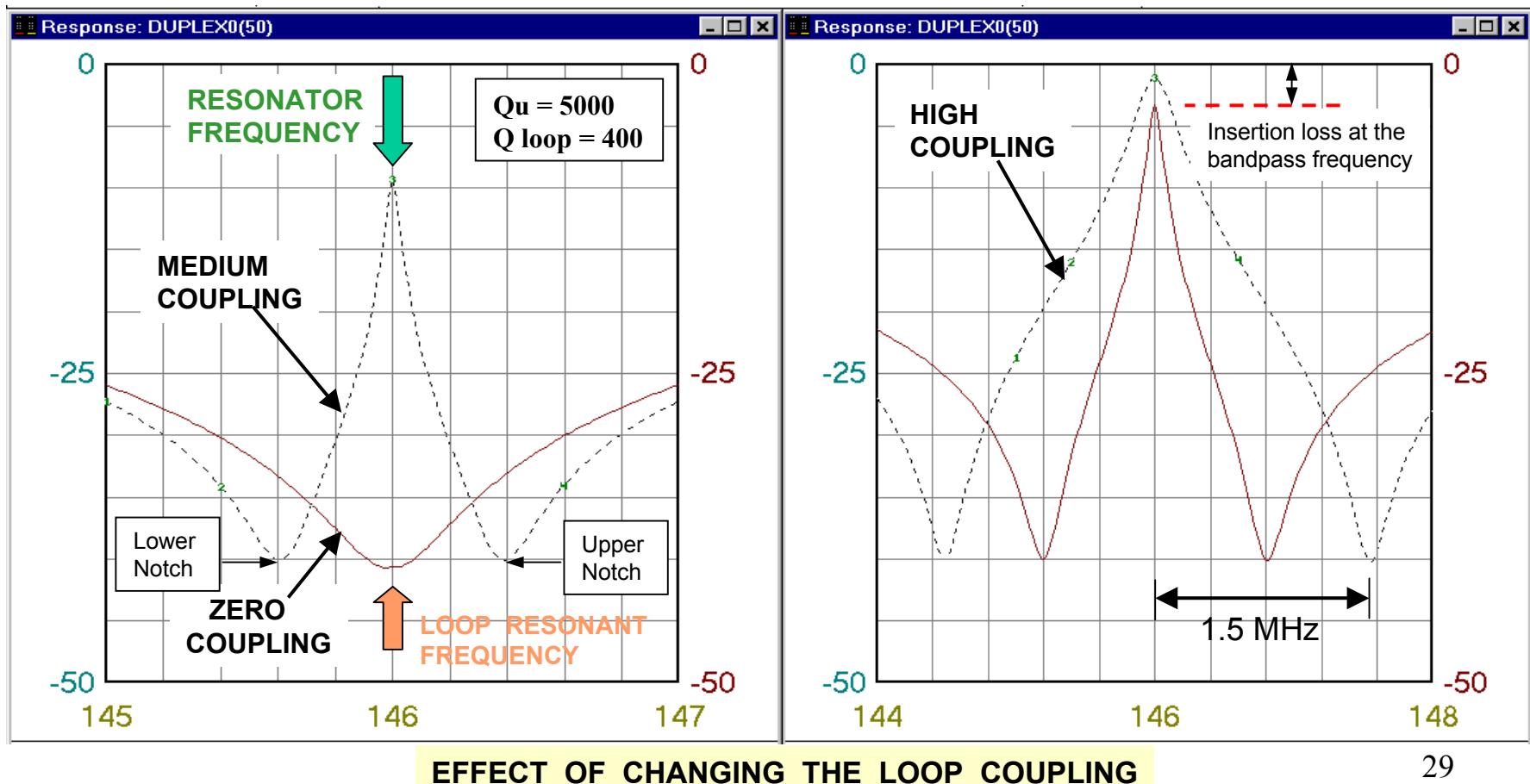
SINGLE LOOP SERIES RESONANT NOTCH-BANDPASS

- THE COUPLING LOOP IS INITIALLY UNCOUPLED FROM THE RESONATOR (Removed from the cavity)
- SERIES CIRCUIT GIVES MAXIMUM ATTENUATION AT SERIES RESONANCE (Coupling is zero)
- NOTCH DEPTH IS A FUNCTION OF THE Q OF THE LOOP (Orange curve)
- THE RESONATOR IS TUNED AT THE SAME FREQUENCY (With the loop inside the cavity and light coupling)



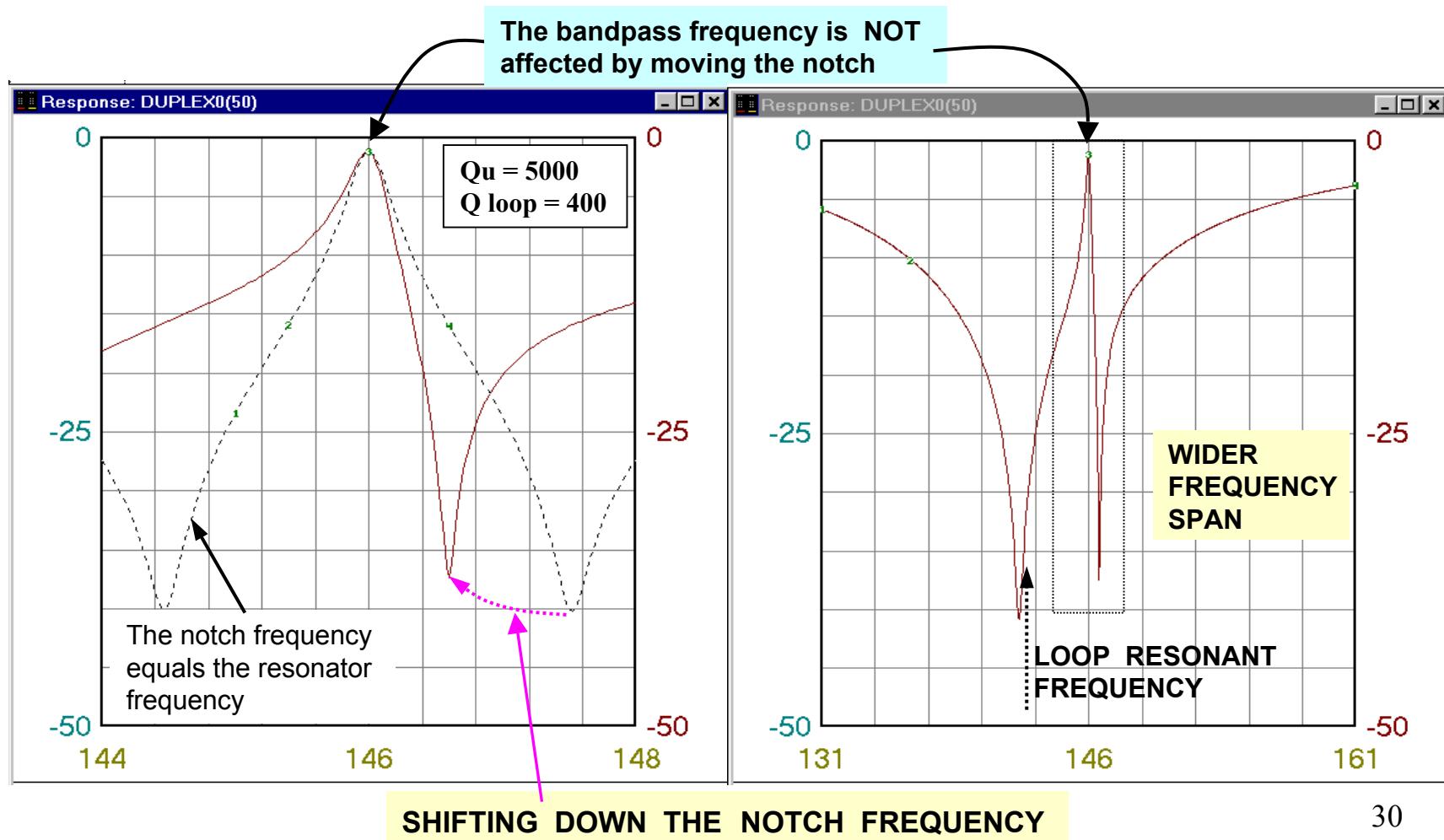
SINGLE LOOP SERIES RESONANT NOTCH-BANDPASS

- INCREASING THE COUPLING SPREADS THE TWO NOTCHES APART AND...
- DECREASES THE INSERTION LOSS AT THE BANDPASS FREQUENCY
- FOR 1 dB LOSS THE NOTCHES ARE AT +/- 1.5 MHz – NEED TO SHIFT THE DESIRED NOTCH



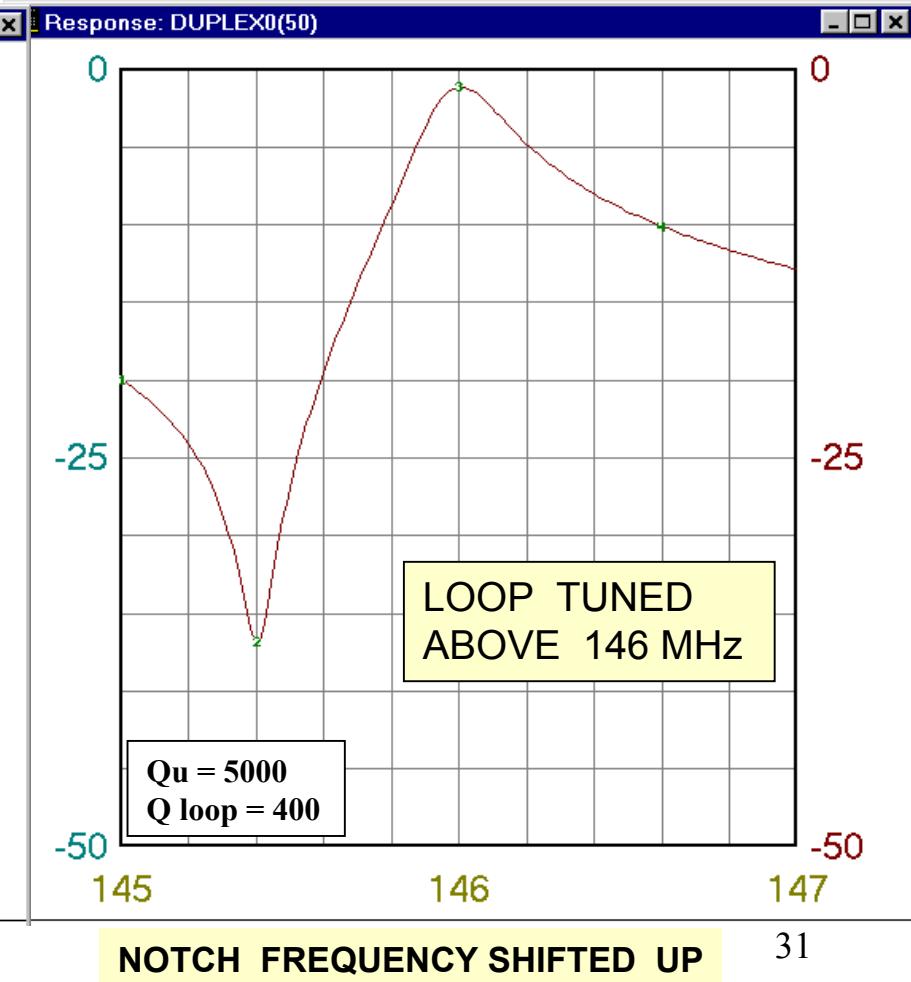
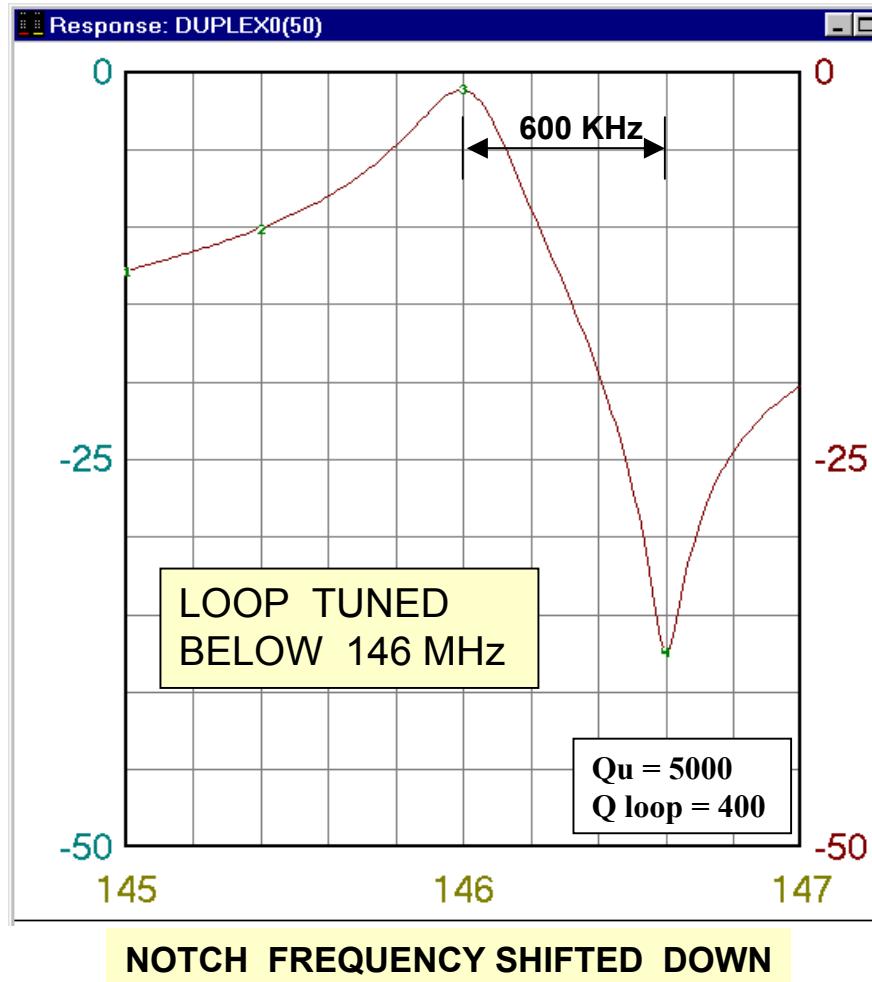
SINGLE LOOP SERIES RESONANT NOTCH-BANDPASS

- THE UPPER NOTCH FREQUENCY IS SHIFTED DOWN BY LOWERING THE LOOP RESONANT FREQUENCY (SOLID BROWN CURVE)
- THE DEPTH OF THE UPPER NOTCH SUFFERS



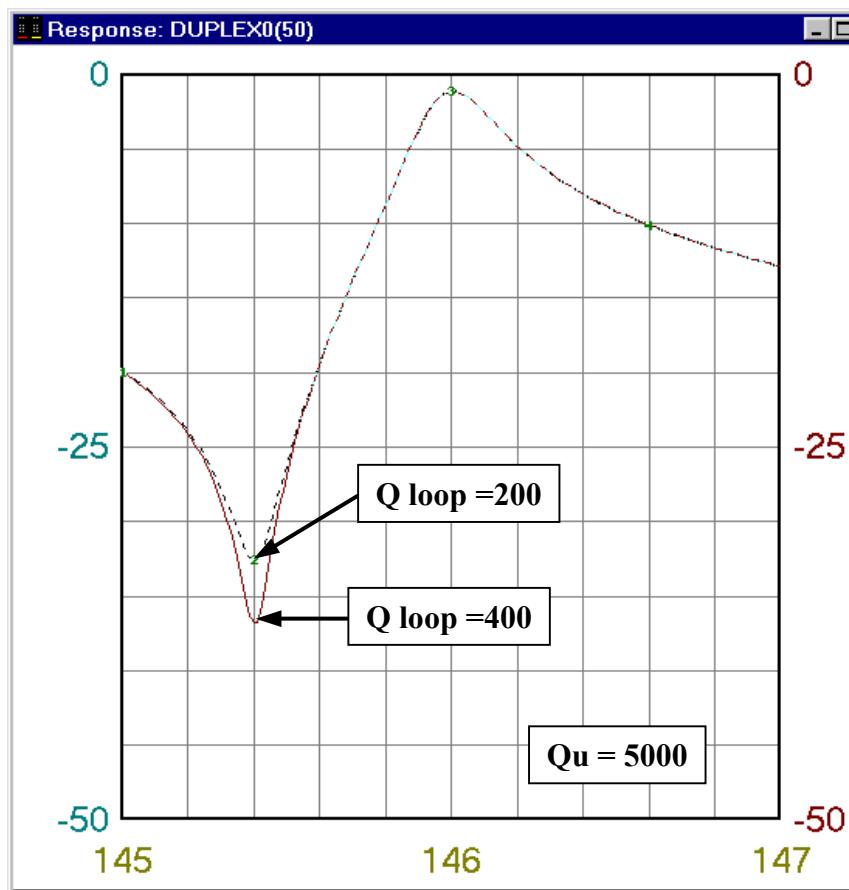
SINGLE LOOP SERIES RESONANT NOTCH-BANDPASS

- TUNING THE LOOP BELOW AND ABOVE THE BANDPASS FREQUENCY WILL SET THE NOTCH +/- 600 KHz

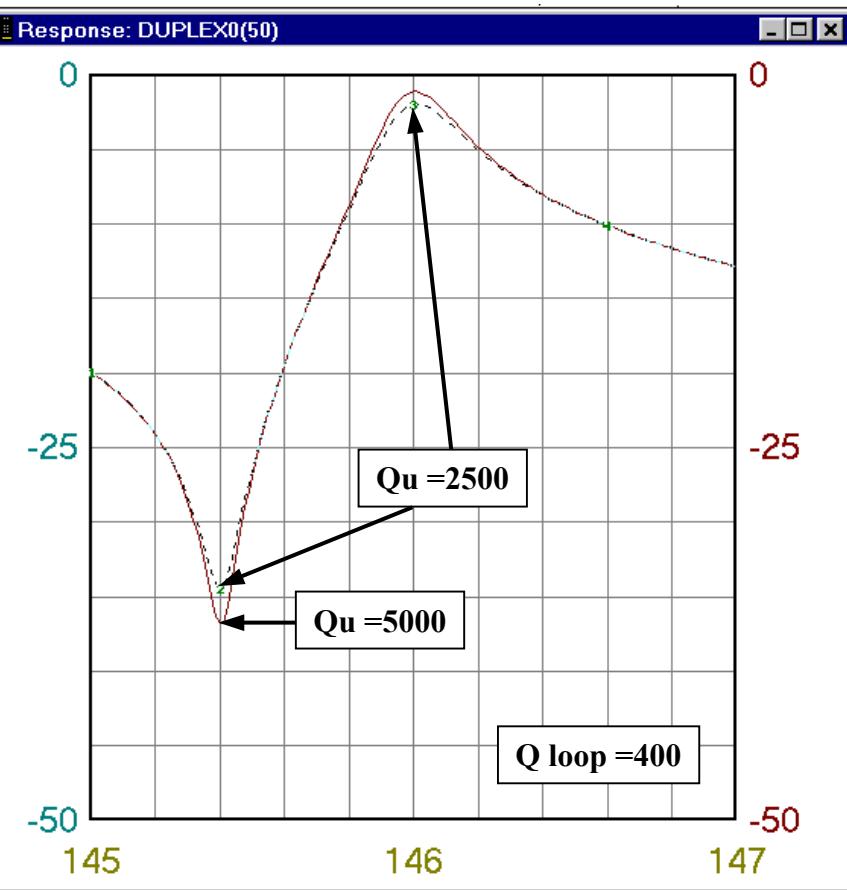


SINGLE LOOP SERIES RESONANT NOTCH-BANDPASS

- THE Q OF THE LOOP SETS THE NOTCH DEPTH

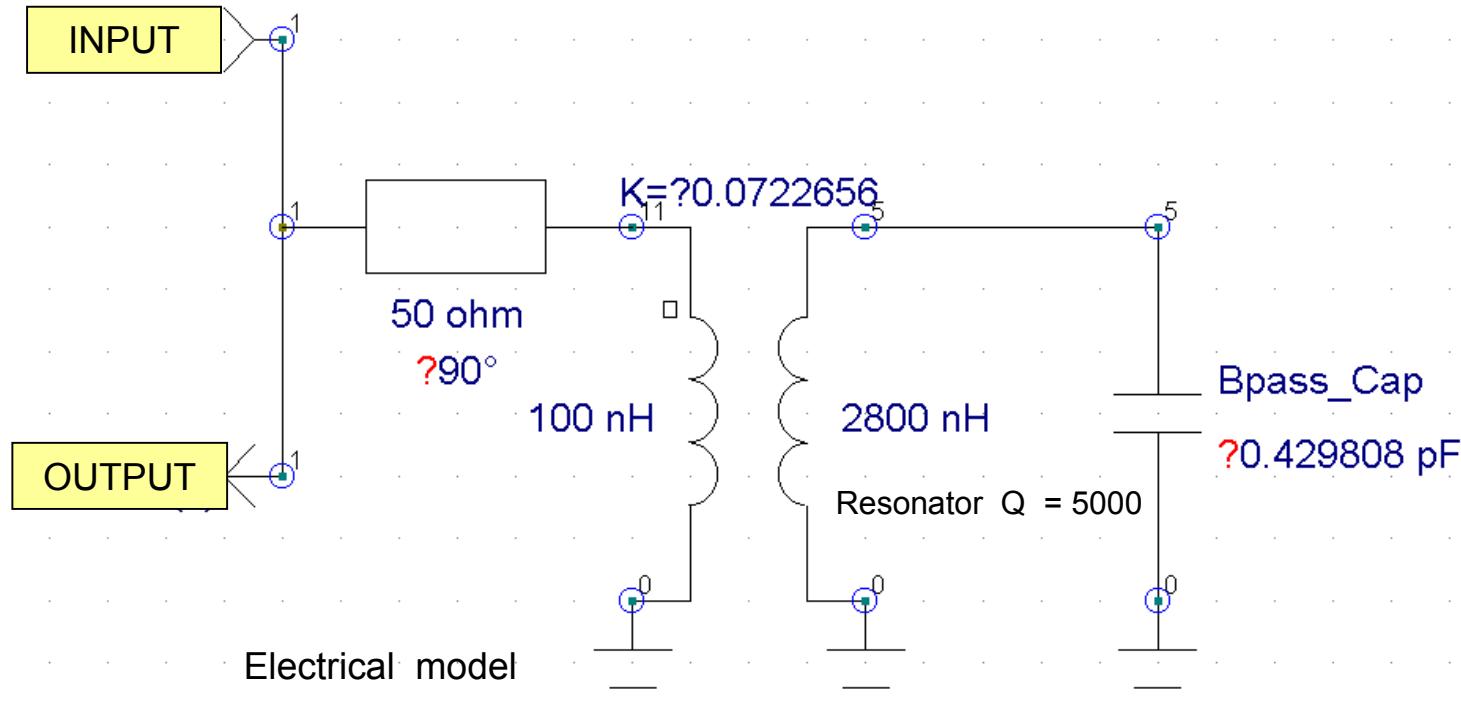


- THE Q OF THE CAVITY (Qu) AFFECTS BOTH THE BANDPASS LOSS AND THE NOTCH DEPTH



SINGLE LOOP SERIES NON-RESONANT NOTCH-BANDPASS

- UNTUNED COUPLING LOOP IN SERIES WITH A TRANSMISSION LINE
- PROVIDES NOTCH-BANDPASS OPERATION
- THE LINE LENGTH AND THE LOOP COUPLING ARE ADJUSTED TO OBTAIN THE DESIRED NOTCH BANDPASS RESPONSE.
- GIVES 2 NOTCHES AS IN THE RESONANT NOTCH BANDPASS



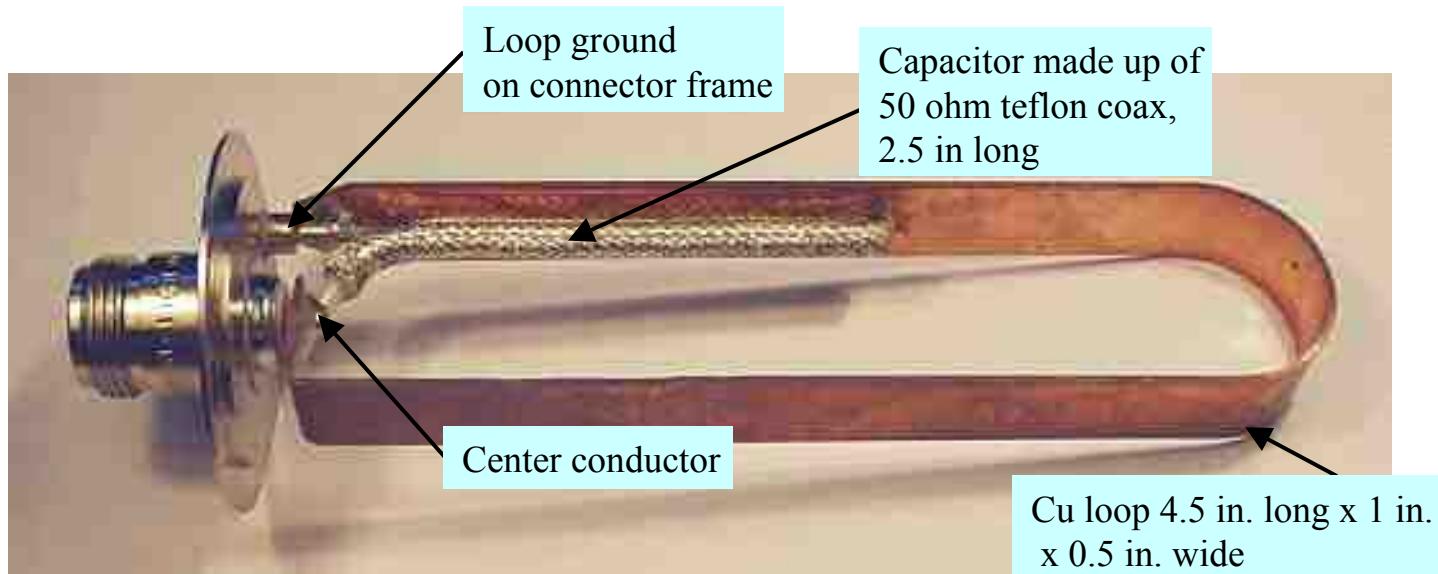
Thanks to: Pedro M.J. Wyns (ON7WP-AA9HX)

NOTCH – BANDPASS MODE PARALLEL RESONANT LOOP CAVITIES

- DUAL LOOP NOTCH-BANDPASS CAVITIES
- SINGLE LOOP SERIES RESONANT NOTCH-BANDPASS
- ➡ □ SINGLE LOOP PARALLEL RESONANT NOTCH-BANDPASS (Q circuit)

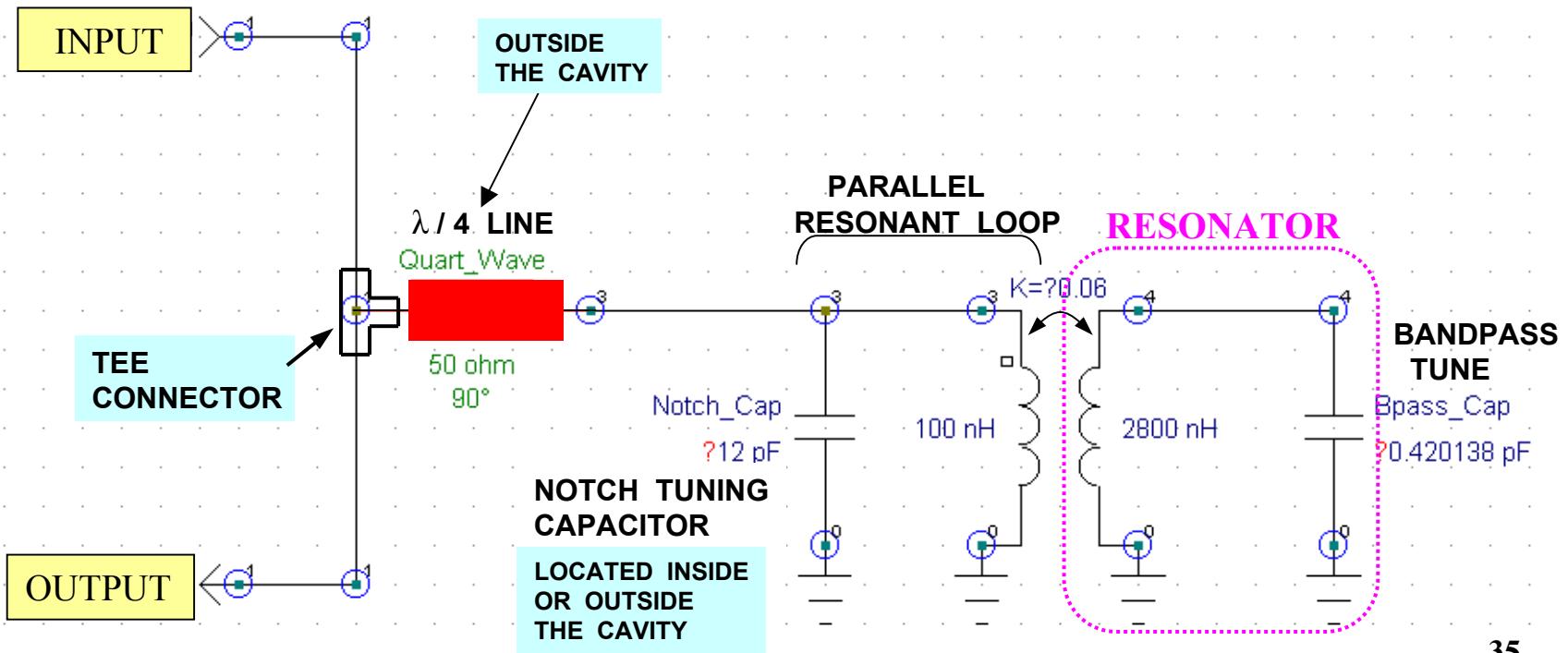
PARALLEL RESONANT LOOP (Q circuit)

- EXAMPLE OF A PARALLEL RESONANT LOOP
- HERE THE CAPACITOR IS MADE WITH A SHORT LENGTH OF COAX



PARALLEL RESONANT LOOP (Q circuit)

- A QUARTER WAVELENGTH LINE TRANSFORMS THE LOOP PARALLEL CIRCUIT INTO A SERIES CIRCUIT – EFFECTIVELY
- OPERATION IS SIMILAR TO THE SERIES RESONANT LOOP
- TWO NOTCHES ARE ALWAYS PRESENT WITH THIS CONFIGURATION



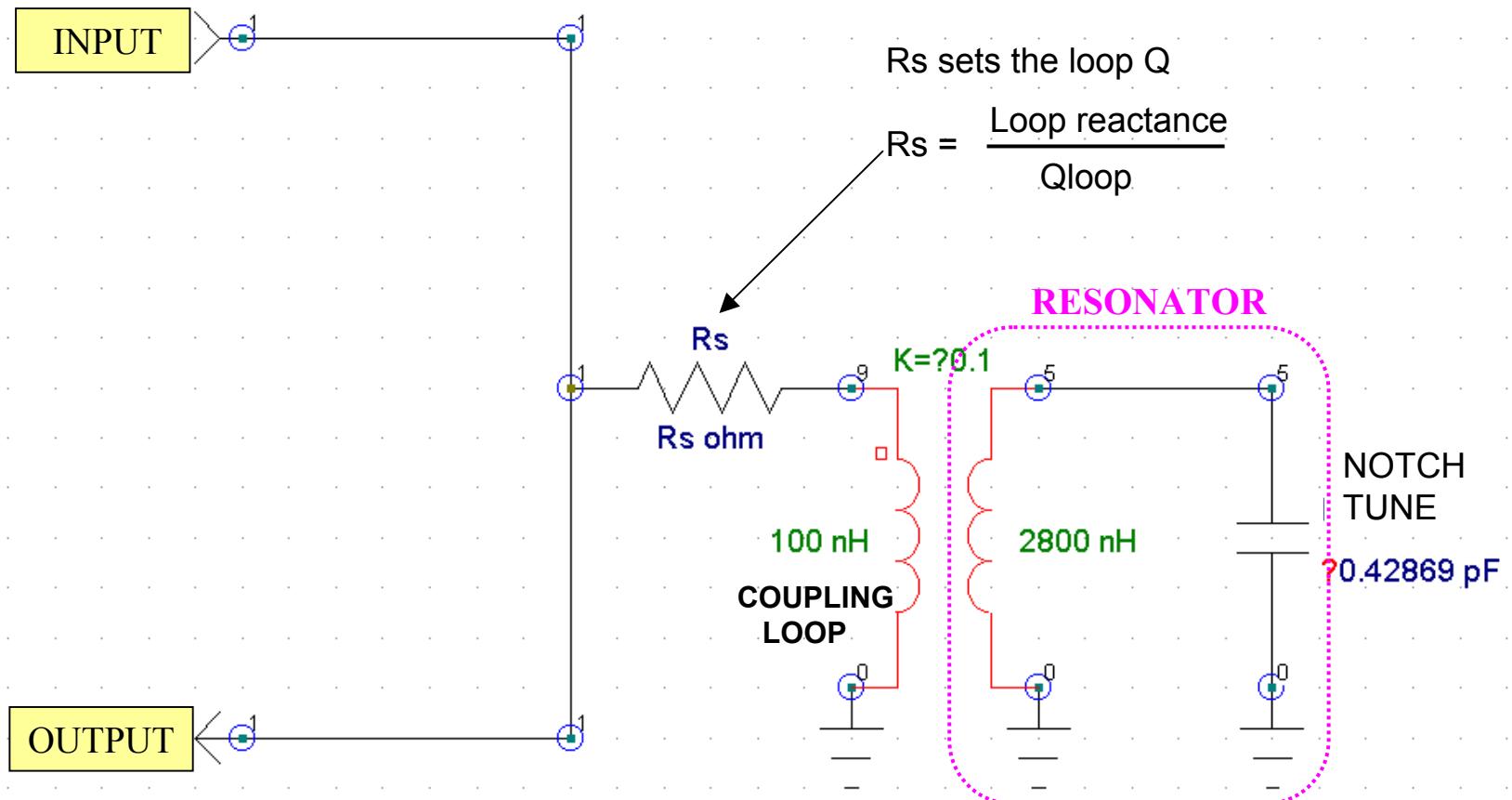
NOTCH CAVITIES

➡ CAVITY NOTCHERS

HELIAX NOTCHERS

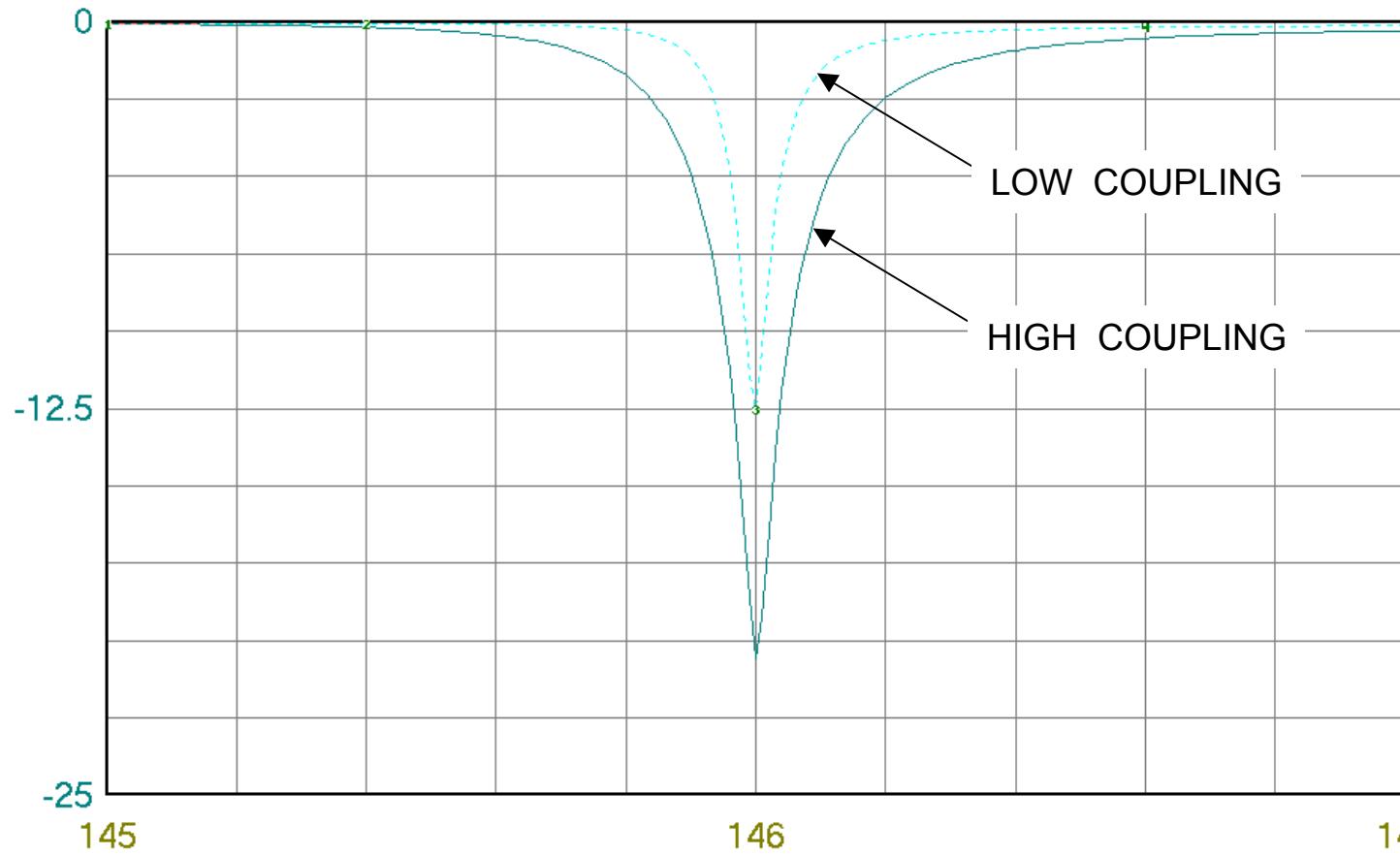
CAVITY NOTCHER for 146 MHz

EQUIVALENT CIRCUIT



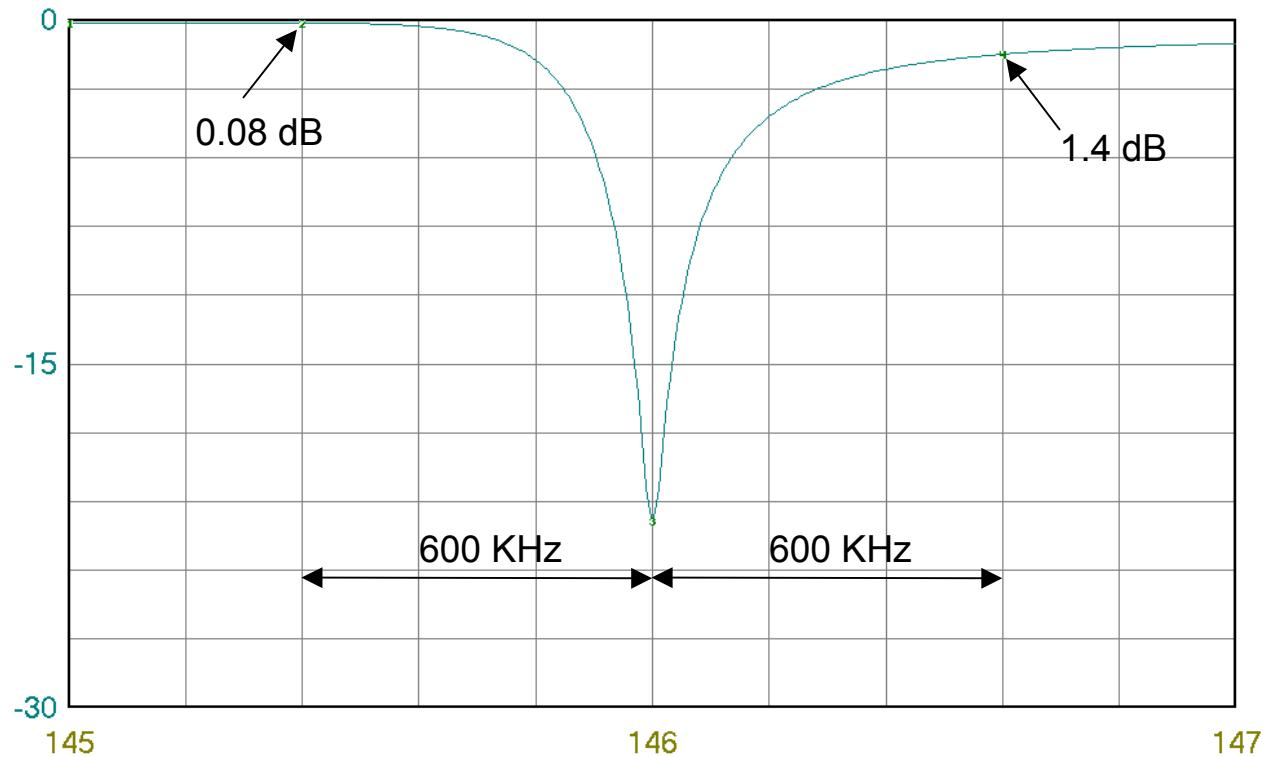
CAVITY NOTCHER FREQUENCY RESPONSE

- ❑ VARYING THE LOOP COUPLING AFFECTS THE NOTCH DEPTH AND
- ❑ DETUNES THE NOTCH FREQUENCY SOMEWHAT



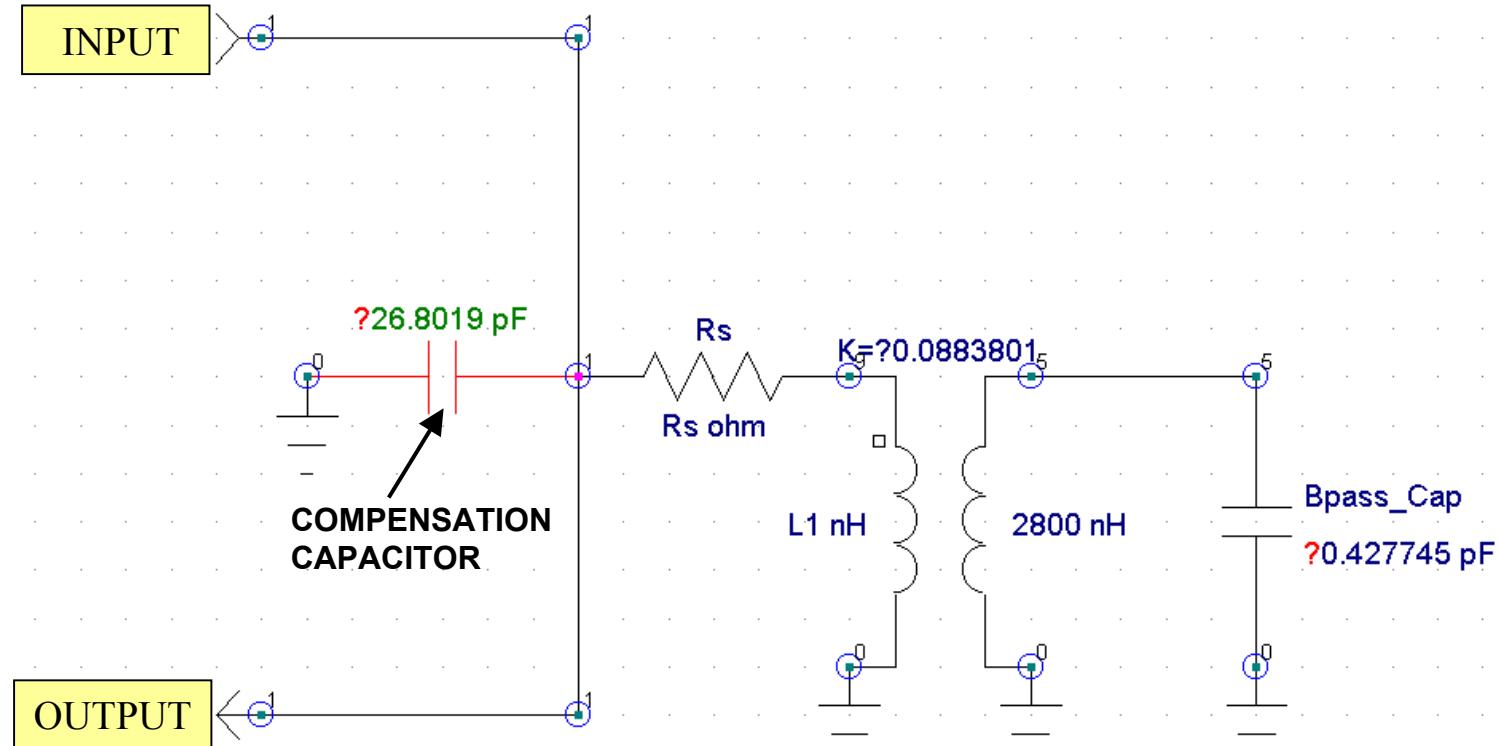
CAVITY NOTCHER FREQUENCY RESPONSE

- ❑ RESPONSE NOT SYMETRICAL AT +/- 600 KHz
- ❑ HIGH SIDE HAS A LOT MORE ATTENUATION AT + 600KHz



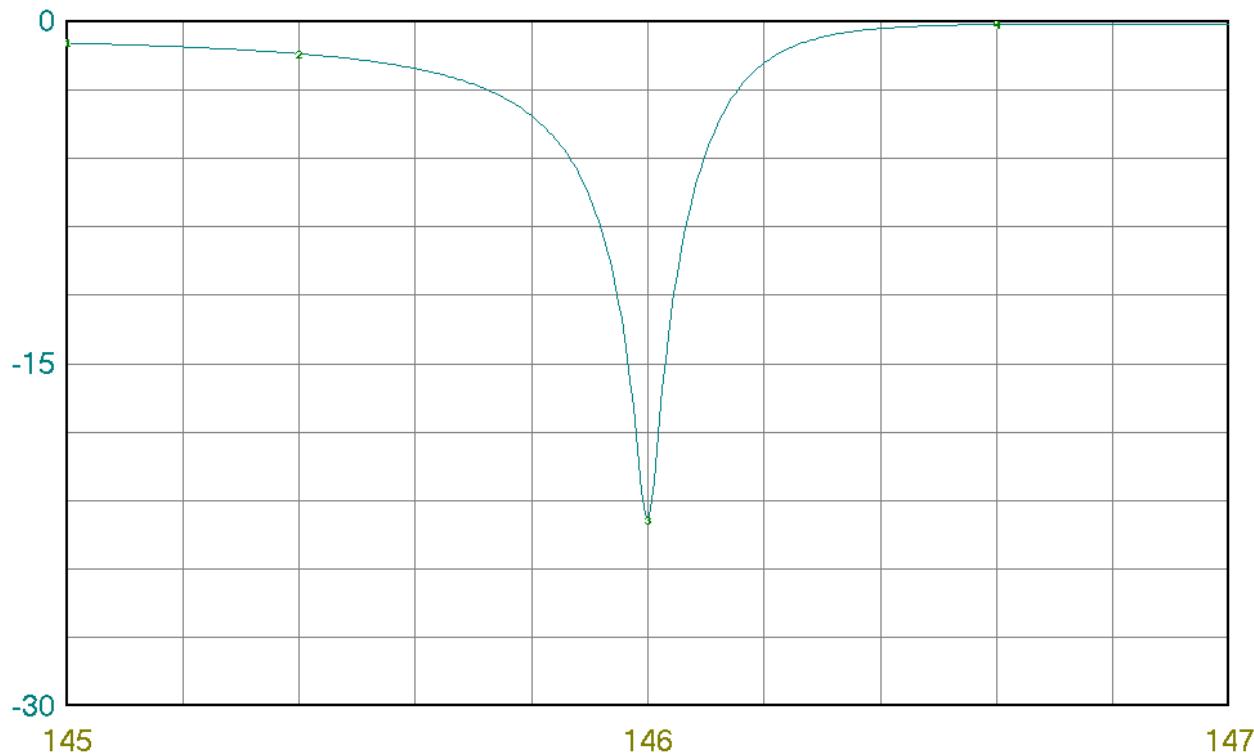
CAVITY NOTCHER WITH COMPENSATION CAPACITOR

- ADDING A COMPENSATION CAPACITOR DECREASES THE LOSSES ON THE UPPER SIDE
- THE COMPENSATION CAPACITOR HAS AN OPTIMUM VALUE FOR A GIVEN SPLIT
- ITS Q FACTOR IS NOT CRITICAL - AN OPEN COAX STUB MAY BE USED



CAVITY NOTCHER WITH COMPENSATION CAPACITOR

- ❑ CONSIDERABLY REDUCED HIGH SIDE INSERTION LOSS
- ❑ LOW SIDE NOW HAS THE HIGH INSERTION LOSS

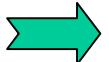


CAVITY NOTCHERS - GENERAL

- ❑ OBTAINING THE DEEPEST NOTCH REQUIRES:
 - INCREASING THE LOOP COUPLING
 - DECREASING THE LOOP INDUCTANCE
- ❑ THESE TWO REQUIREMENTS ARE CONTRADICTORY SINCE
 - A LOW INDUCTANCE LOOP WILL HAVE LESS COUPLING AND VICE VERSA
- ❑ IT MAY BE DIFFICULT TO GET 30 dB REJECTION ON A 6 in. CAVITY
- ❑ THE LOW SIDE MAY HAVE TO BE COMPENSATED WITH AN INDUCTOR
 - TO ACHIEVE MINIMUM LOSSES (OR A SHORTED STUB)
- ❑ THE Q FACTOR OF THE LOOPS IS NOT CRITICAL, AS LONG AS $Q > 100$ OR SO
- ❑ THE NOTCH - BANDPASS MODE MAKES A MORE EFFICIENT USE OF THE CAVITY.
 - NOTCH DEPTHS BETTER THAN 35 dB ARE EASILY OBTAINED WITH A 6 in. CAVITY

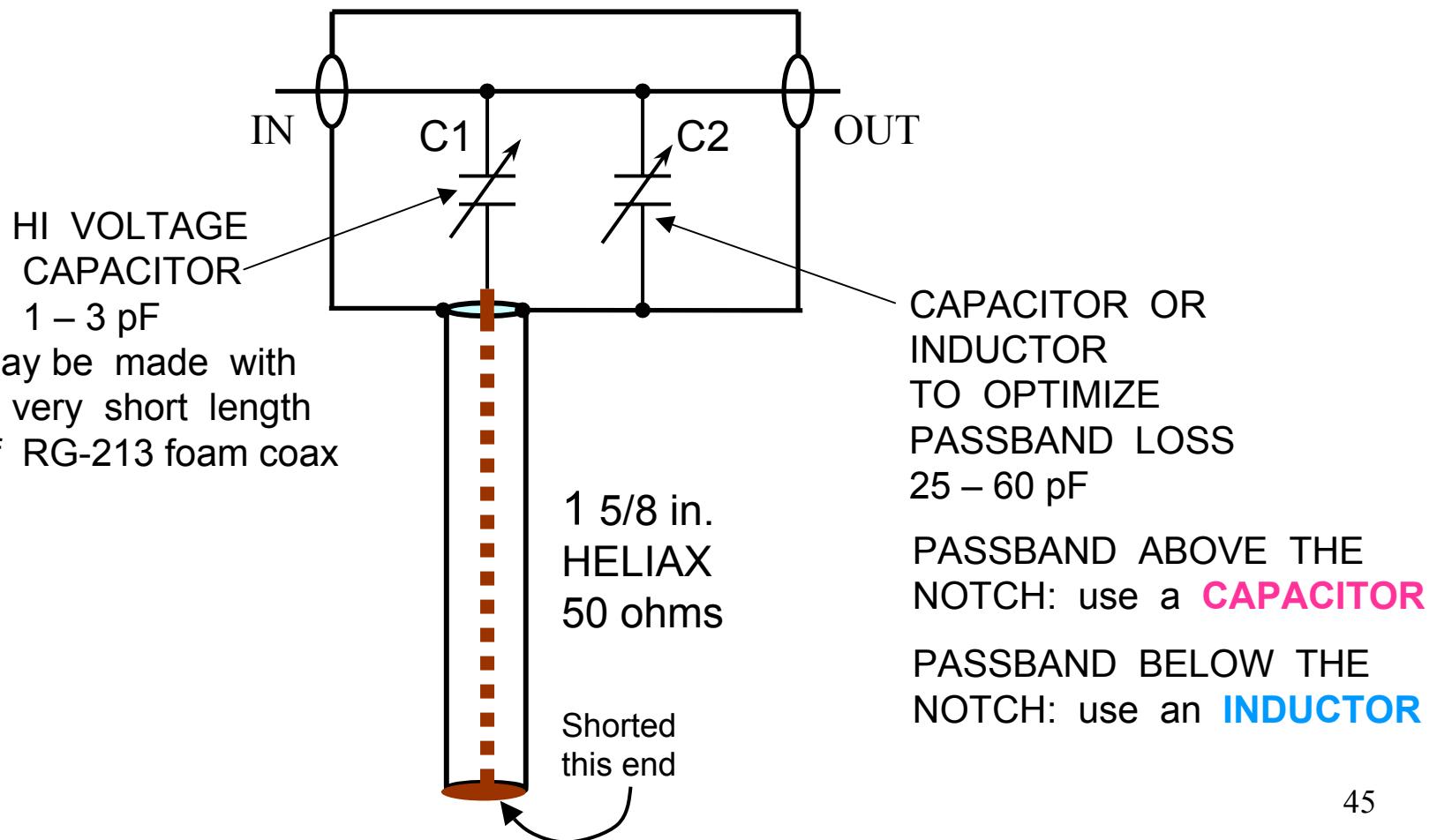
NOTCH CAVITIES

CAVITY NOTCHERS

 HELIAX NOTCHERS

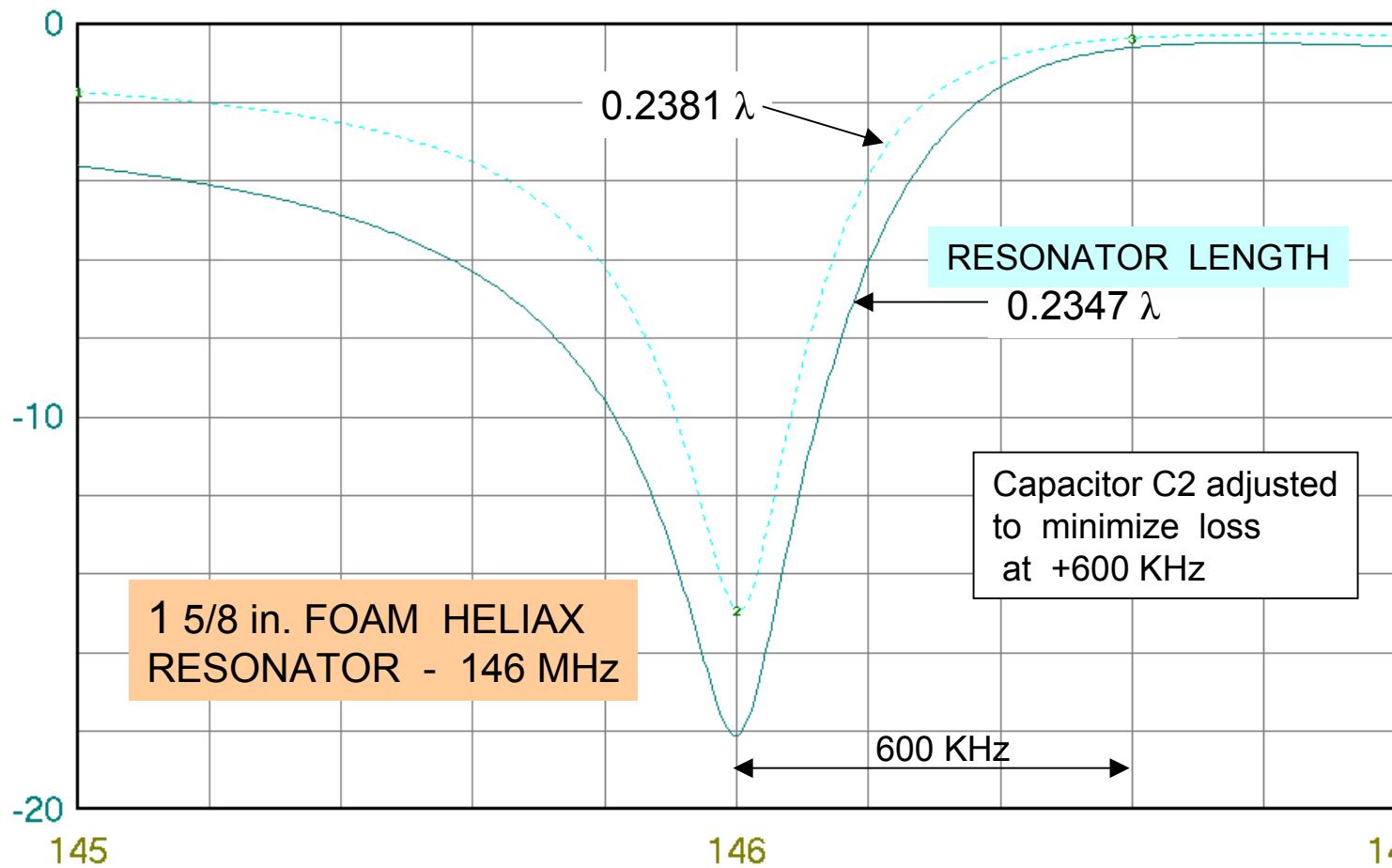
HELIAX NOTCHER for 146 MHz

- ❑ USES AN INDUCTIVE SHORTED STUB See ref. 3 and 4
- ❑ THE STUB EXHIBITS SERIES RESONANCE AT THE NOTCH FREQUENCY



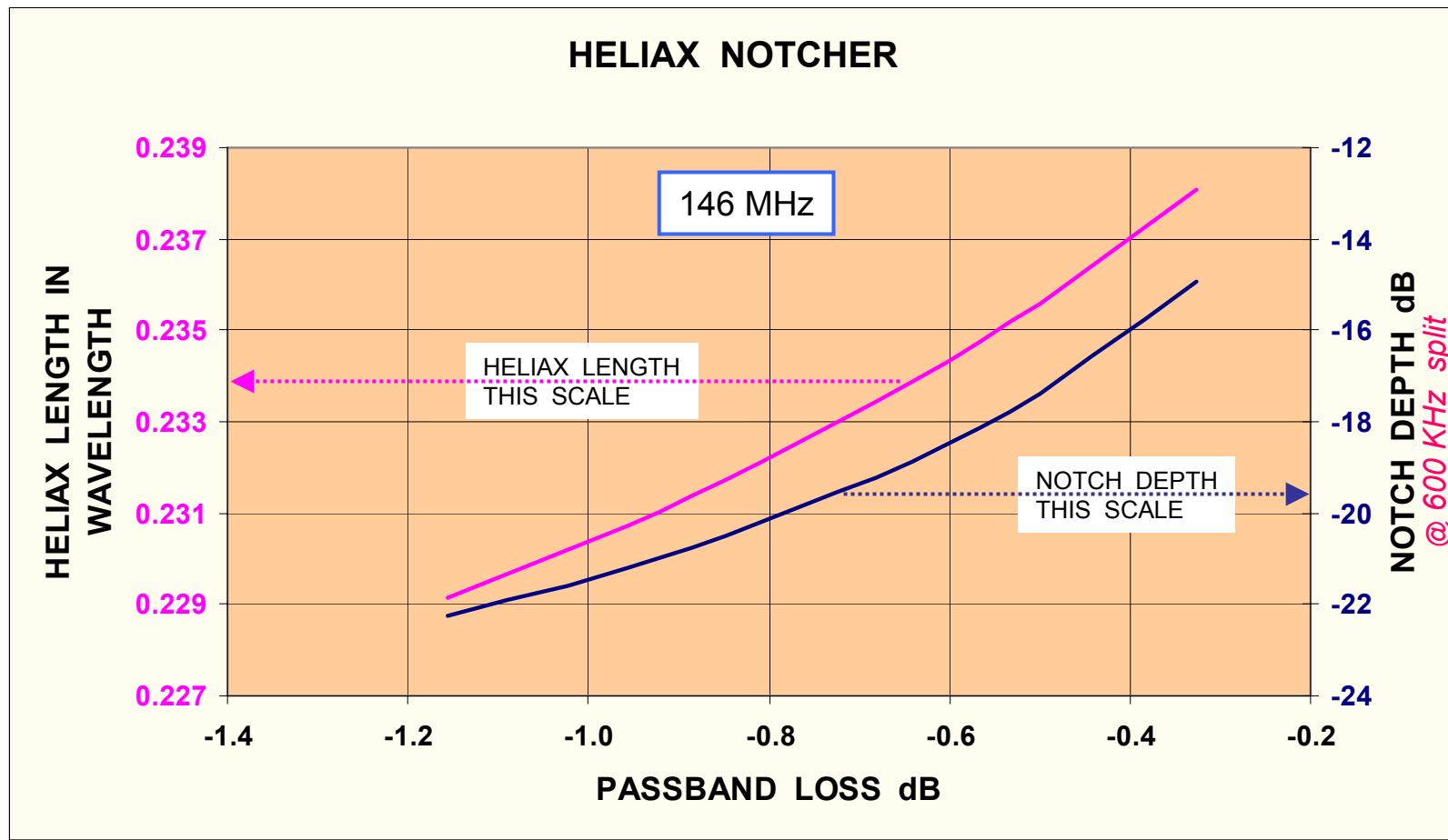
HELIAX NOTCHER - FREQUENCY RESPONSE

1 5/8 in. FOAM HELIAX $V_f=0.87$ 50 ohms 0.156 dB/100 ft @ 50 MHz
Series cap = 50 ohm foam coax $V_f=0.87$ 2.2 dB/100 ft @ 150 MHz



ATTENUATION AND LENGTH DATA FOR THE HELIAX NOTCHER

1 5/8 in. FOAM HELIAX $V_f=0.87$ 50 ohms 0.156 dB/100 ft @ 50 MHz
Series cap = 50 ohm foam coax $V_f=0.87$ 2.2 dB/100 ft @ 150 MHz

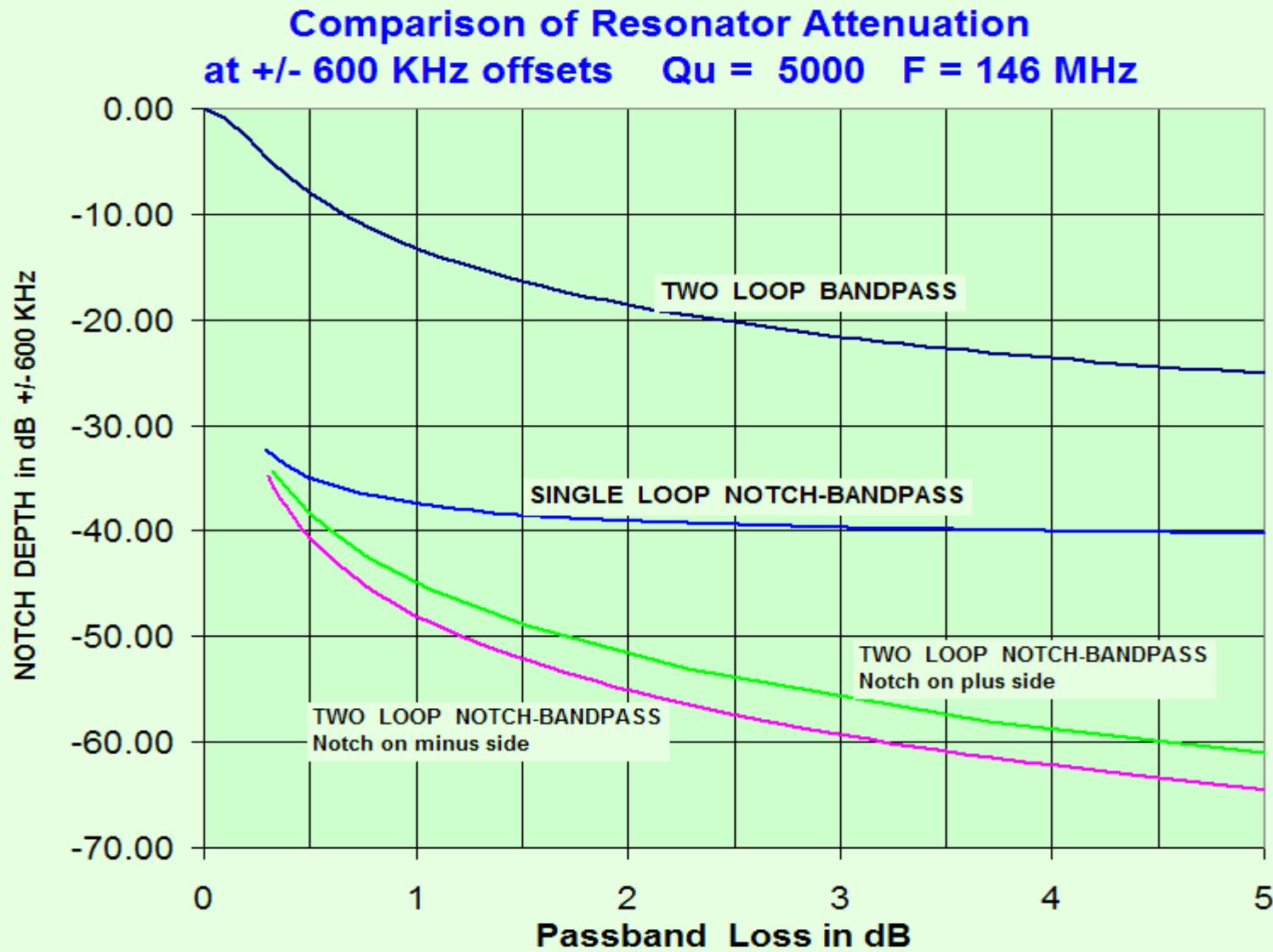


NOTE: Use with a $\lambda/4$ connecting line. The line adds ~ 5 dB to the notch depth

COMPARISONS

CAVITY TYPE	PLUS	MINUS
BANDPASS	<ul style="list-style-type: none"> • EASIEST TO ADJUST • INCREASING REJECTION OF OUTSIDE SIGNALS 	<ul style="list-style-type: none"> • POOR REJECTION CLOSE TO BANDPASS (12-18 dB @ 600 KHz on 2m)
DUAL LOOP NOTCH-BANDPASS	<ul style="list-style-type: none"> • BEST NOTCH DEPTH ~ 45 dB typical 6" cavity • ONLY ONE NOTCH • NOTCH TUNE SENSITIVITY IS LOW: 16% / 100KHz 	<ul style="list-style-type: none"> • FLOATING SERIES CAPACITOR • SERIES INDUCTOR DIFFICULT TO ADJUST • SOME REJECTION OUTSIDE BANDPASS • NOTCH FREQ. INTERACTS SOMEWHAT WITH BANDPASS FREQUENCY
SINGLE LOOP SERIES RESONANT NOTCH-BANDPASS	<ul style="list-style-type: none"> • EASY TO ADJUST VIA SER CAP OR COUPLING • GOOD NOTCH DEPTH ~ 37 dB typical 6" cavity • NOTCH FREQ. INDEPENDANT OF BANDPASS FREQUENCY 	<ul style="list-style-type: none"> • TWO NOTCHES – MISLEADING • NOTCH TUNE SENSITIVITY IS HIGH: -1% / 100KHz • LOOP Q DETERMINES NOTCH DEPTH • LITTLE REJECTION OUTSIDE BANDPASS AND NOTCH
SINGLE LOOP PARALLEL RESONANT NOTCH-BANDPASS (Q circuit)	<ul style="list-style-type: none"> • SAME AS SERIES RESONANT LOOP 	<ul style="list-style-type: none"> • SAME AS SERIES RESONANT LOOP • QUARTER WAVELENGTH CABLE INTRODUCE ADDITIONAL LOSSES
NOTCH CAVITIES	<ul style="list-style-type: none"> • ATTENUATE A NARROW BAND OF FREQUENCIES • MAY BE BUILT USING HELIAX CABLE 	<ul style="list-style-type: none"> • NOTCH DEPTH NOT AS GOOD AS IN NOTCH-BANDPASS DESIGNS • USE WITH BANDPASS CAVITIES TO PROVIDE REJECTION FAR FROM TX/RX

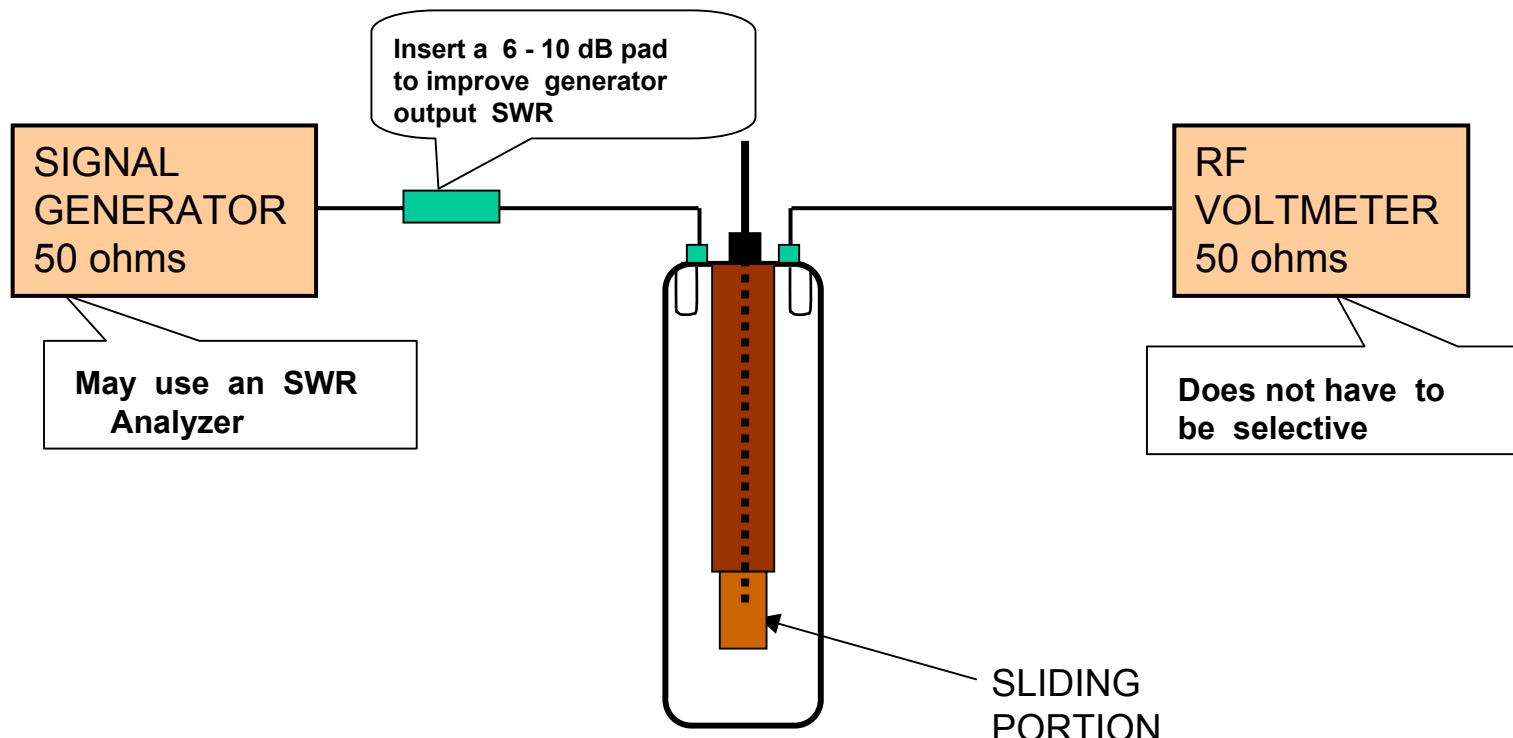
COMPARISONS



TUNING INDIVIDUAL CAVITIES

TUNING BANDPASS CAVITIES

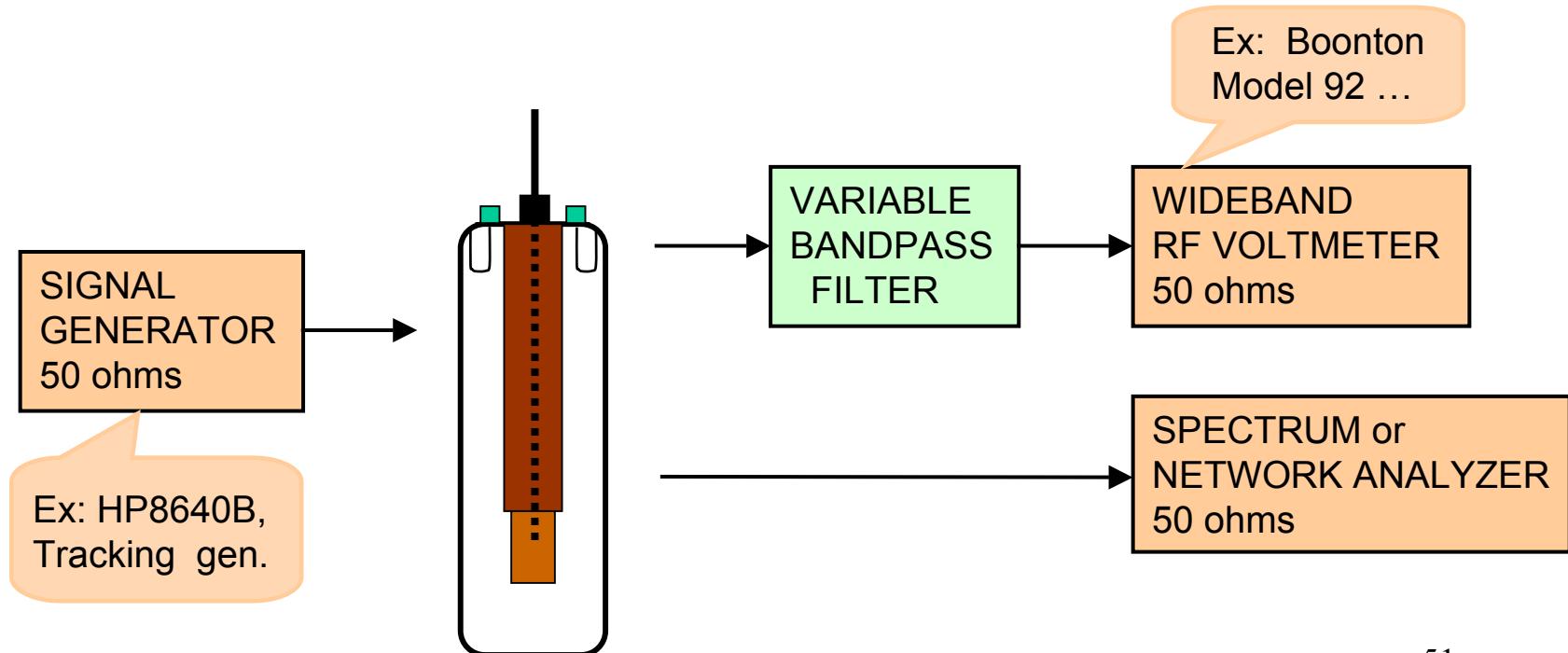
- ADJUST THE BANDPASS FREQUENCY FOR MAXIMUM SIGNAL
- CHECK THE INSERTION LOSS. CHANGE THE LOOP COUPLING IF REQ'D



TUNING NOTCH - BANDPASS CAVITIES

ABOUT THE VOLTMETER...

- ❑ WIDE BAND VOLTMETERS MAY PICK UP GENERATOR HARMONICS WHEN MEASURING NOTCH DEPTH
- ❑ A SELECTIVE VOLTMETER IS REQUIRED



TUNING NOTCH - BANDPASS CAVITIES

DUAL LOOP CAVITIES (MODIFIED BANDPASS TYPES)

- ❑ ADJUST THE BANDPASS FREQUENCY FOR MAXIMUM SIGNAL
- ❑ CHECK THE PASSBAND ATTENUATION AND ADJUST THE LOOP COUPLING AS REQUIRED (typically 0.3 TO 1.5 dB)
- ❑ TO INCREASE THE NOTCH FREQUENCY:
 - DECREASE THE NOTCH CAPACITOR OR
 - DECREASE THE NOTCH INDUCTOR
- ❑ NOTE THAT NOTCH DEPTH GETS WORSE AS THE NOTCH FREQUENCY GETS CLOSER TO THE BANDPASS FREQUENCY
- ❑ ADJUST THE BANDPASS FREQUENCY FOR LOWEST SWR
- ❑ RECHECK THE INSERTION LOSS AT THE BANDPASS FREQUENCY
- ❑ RECHECK THE NOTCH FREQUENCY AND DEPTH

TUNING NOTCH - BANDPASS CAVITIES

SERIES OR PARALLEL LOOP CAVITIES

- ❑ ADJUST THE BANDPASS FREQUENCY FOR MAXIMUM SIGNAL
- ❑ CHECK THE PASSBAND ATTENUATION AND ADJUST THE LOOP COUPLING AS REQUIRED (typically 0.3 TO 1.5 dB)
- ❑ TO INCREASE THE NOTCH FREQUENCY:
 - UPPER NOTCH - ABOVE BANDPASS:
DECREASE THE NOTCH CAPACITOR OR INCREASE COUPLING
 - LOWER NOTCH - BELOW BANDPASS:
DECREASE THE NOTCH CAPACITOR OR DECREASE COUPLING
- ❑ NOTE THAT NOTCH DEPTH GETS WORSE AS THE NOTCH FREQUENCY GETS CLOSER TO THE BANDPASS FREQUENCY
- ❑ ADJUST THE BANDPASS FREQUENCY FOR LOWEST SWR
- ❑ RECHECK THE INSERTION LOSS AT THE BANDPASS FREQUENCY
- ❑ RECHECK THE NOTCH FREQUENCY AND DEPTH

NOTCH - BANDPASS CAVITIES

LOOP RESONANCE VERIFICATIONS - SERIES OR PARALLEL LOOPS

BEST DONE WITH THE LOOP REMOVED FROM THE CAVITY

UPPER NOTCH - ABOVE BANDPASS: (see the graph below)

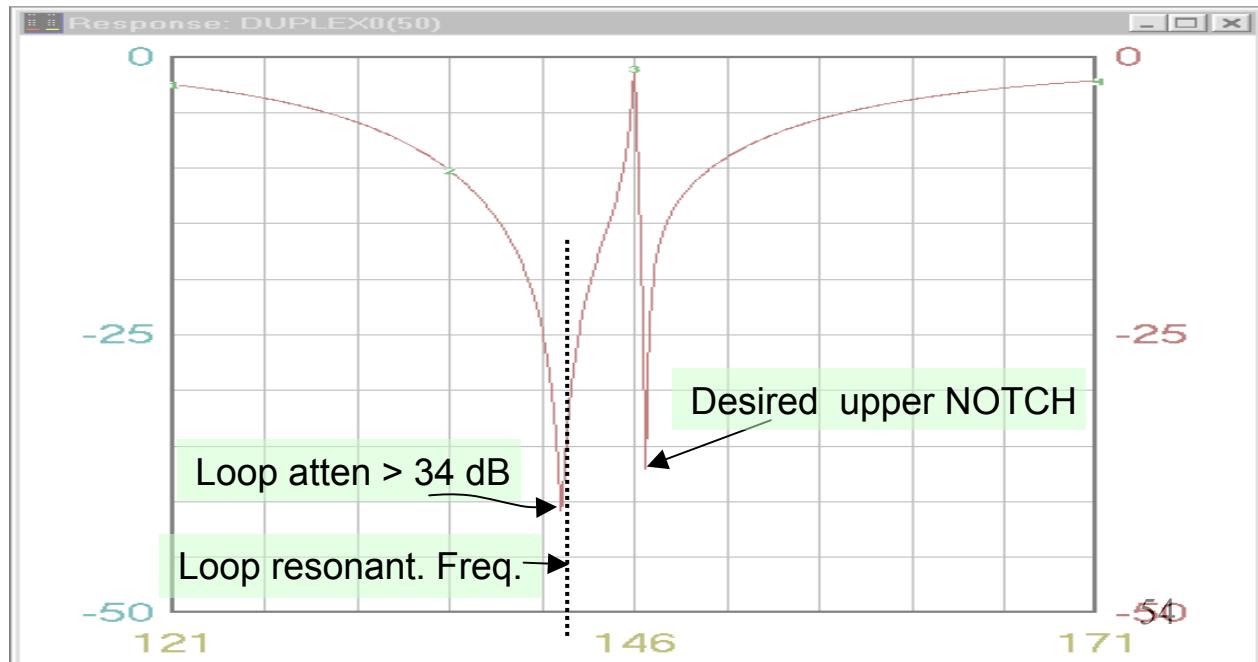
THE LOOP SHOULD RESONATE FROM ~ 130 to 140 MHz

LOWER NOTCH - BELOW BANDPASS:

THE LOOP SHOULD RESONATE FROM ~ 150 to 160 MHz

SHOULD GIVE AT LEAST 34 dB ATTENUATION (IN A 6 in. CAVITY)

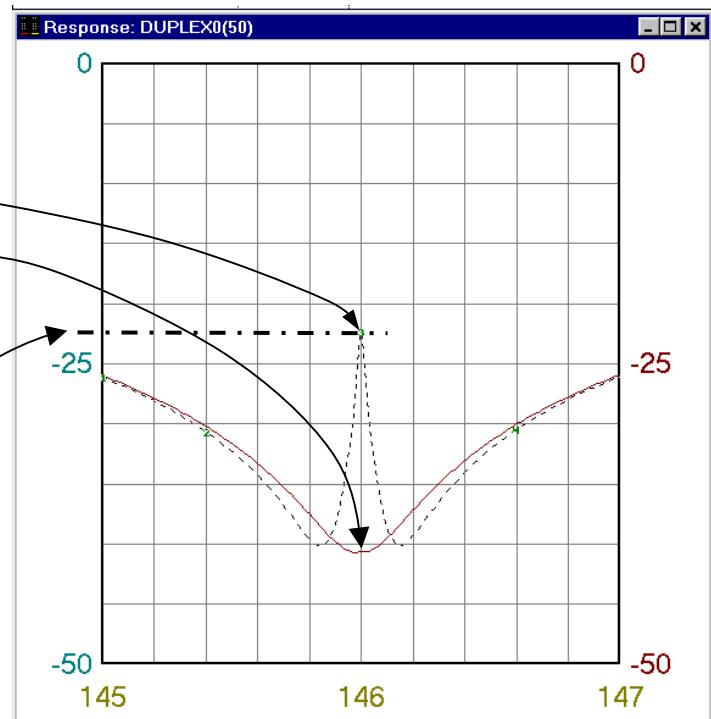
AS SHOWN HERE:
THE LOOP RESONANT
FREQ. AND ATTEN.
MAY ALSO BE OBTAINED
FROM THE CAVITY
RESPONSE



NOTCH - BANDPASS CAVITIES SINGLE LOOP SERIES RESONANT TYPE

Qu FACTOR VERIFICATION

- ADJUST THE RESONATOR
- AND THE COUPLING LOOP (outside the cavity)
- TO RESONATE AT THE SAME FREQUENCY
- ADJUST THE COUPLING FOR
~ 20 dB ATTENUATION
- MEASURE THE -3 dB FREQUENCIES AT THE
PEAK AND CALCULATE Qu AS PREVIOUSLY
DESCRIBED
- THE EXPECTED Qu IS > 5000 FOR A 6 in.
CAVITY

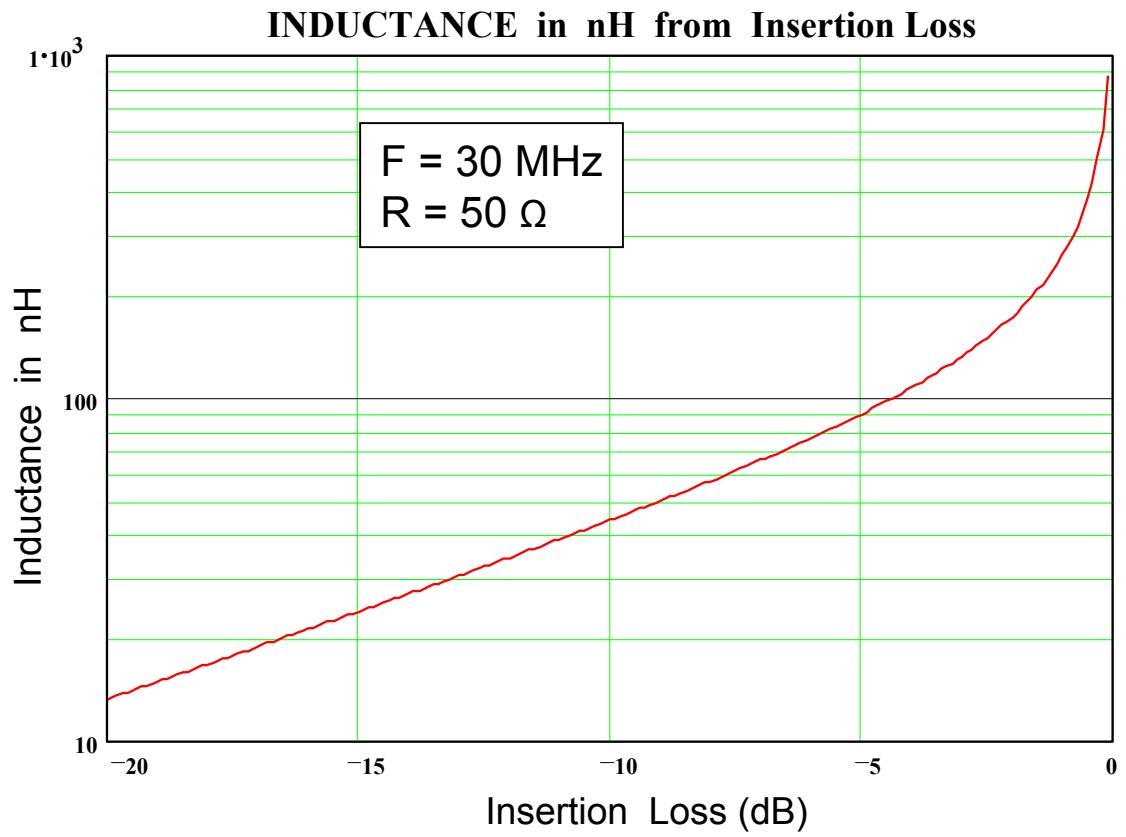


Qu FACTOR VERIFICATION

MEASURING LOOP INDUCTANCE

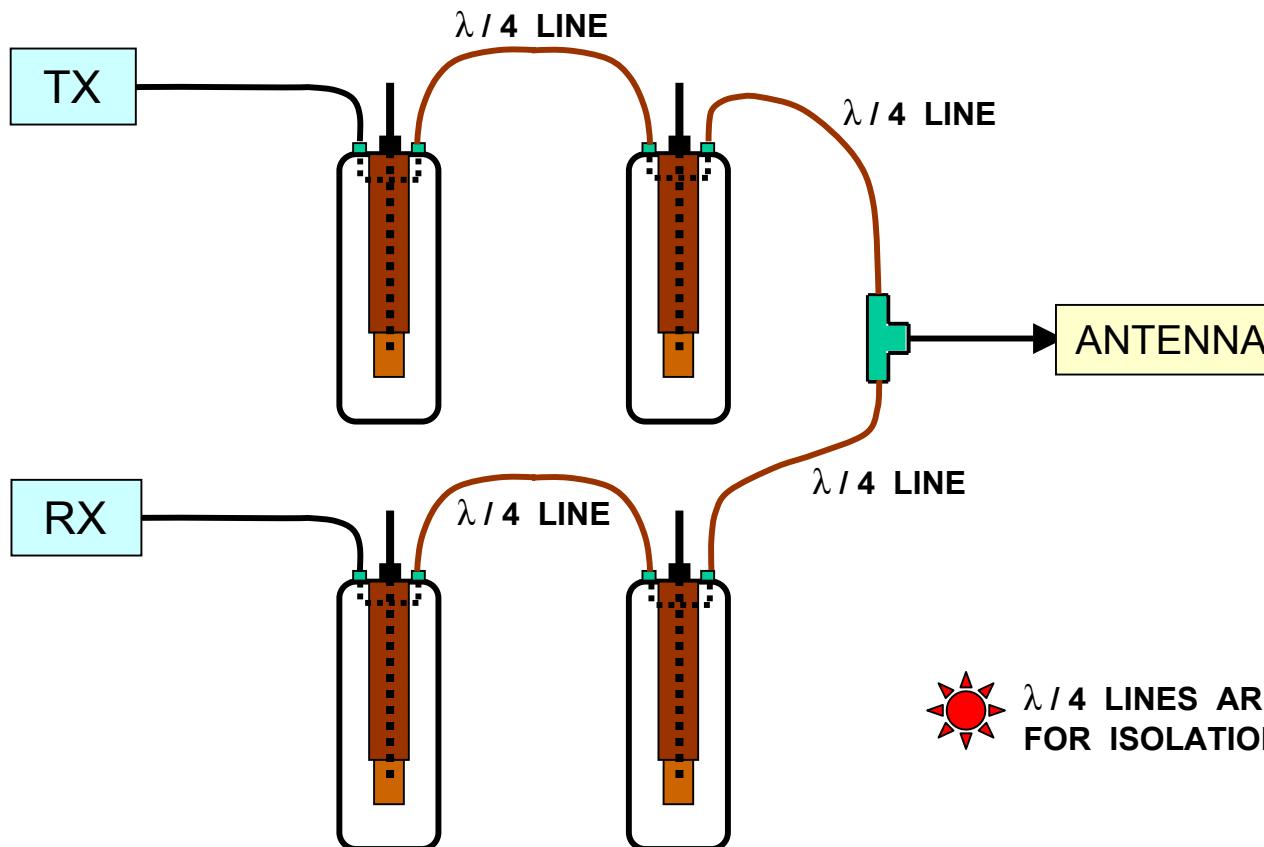
MEASURE THE ATTENUATION IN dB CAUSED BY INSERTING THE LOOP IN A SHUNT CIRCUIT (no series cap.) WITH A GENERATOR / DETECTOR IMPEDANCE = R (ohms) at a FREQUENCY: F in MHz AND COMPUTE THE INDUCTANCE L in nH:

$$L = \frac{79.58 \cdot R \cdot 10^{20} \frac{\text{dB}}{\text{MHz}}}{F \cdot \sqrt{1 - \left[10 \left(\frac{\text{dB}}{20} \right) \right]^2}} \text{ in nH}$$



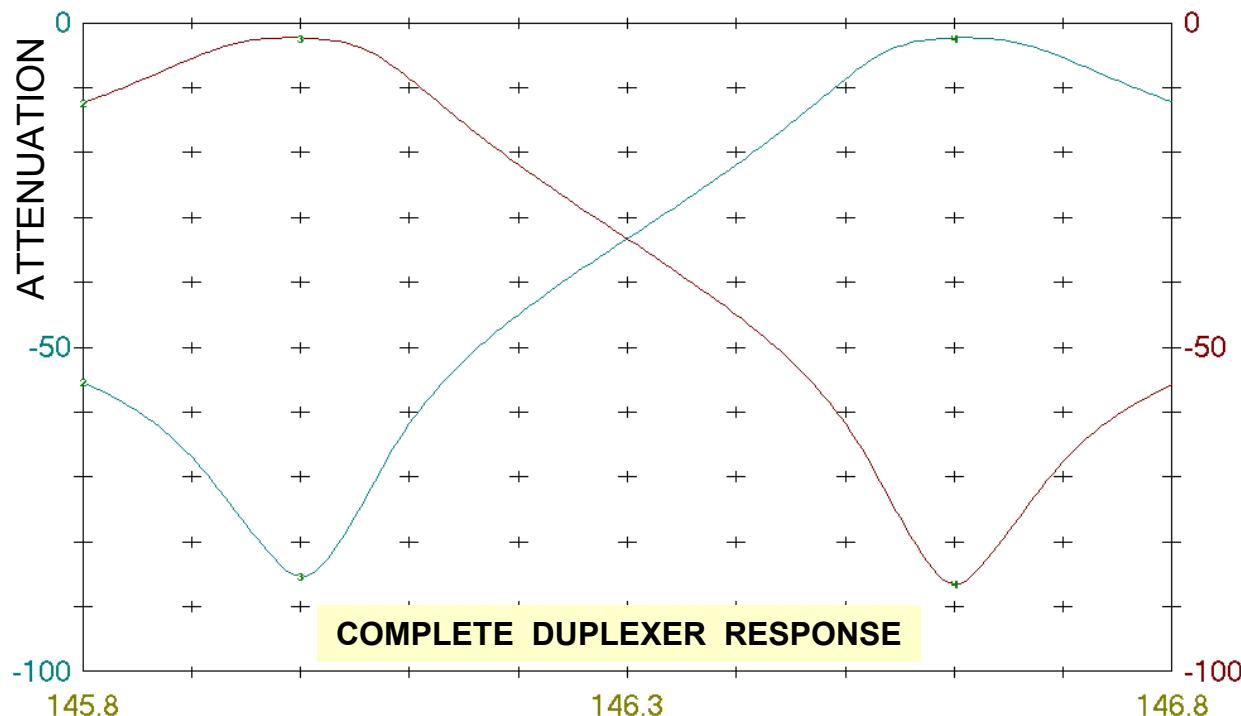
PUTTING IT ALL TOGETHER

DUPLEXER BUILT WITH FOUR 6 in. SERIAL LOOP CAVITIES



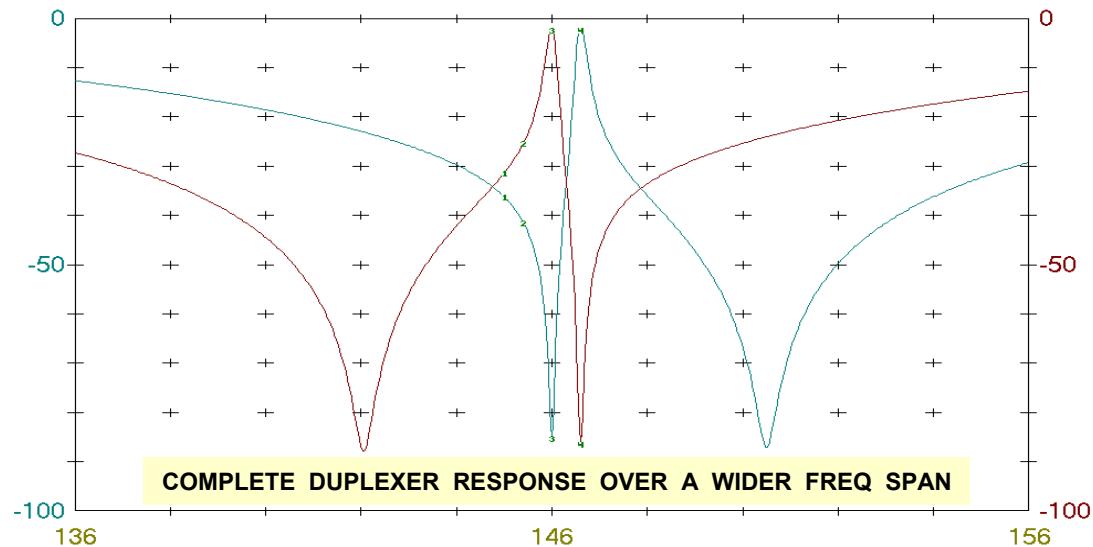
EXAMPLE OF DUPLEXER BUILT WITH FOUR 6 in. SERIAL LOOP CAVITIES

- BANDPASS INSERTION LOSS: ~ 2.2 Db (1 dB PER CAVITY + $\lambda/4$ LINE LOSSES)
- NOTCH DEPTH: ~ 85 dB
- NOTCH DEPTH = ~ SUM OF NOTCH DEPTH OF EACH CAVITY + 5.5 dB **PER** $\lambda/4$ LINE
Example: NOTCH DEPTH = 37 dB + 37 dB + 5.5 x 2 cables = 85 dB

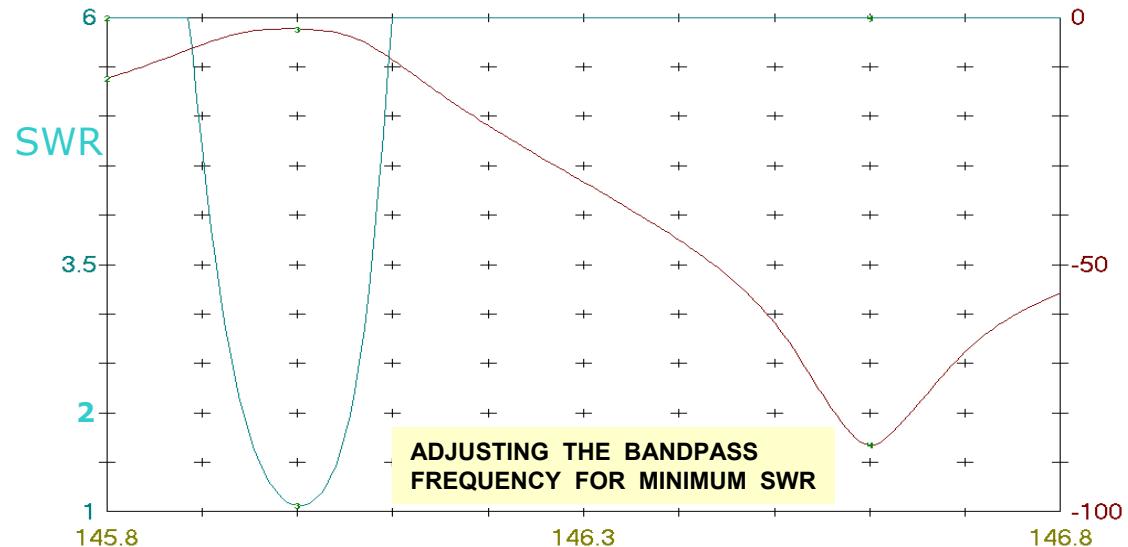


EXAMPLE OF DUPLEXER BUILT WITH FOUR 6 in. SERIAL LOOP CAVITIES

- ❑ THIS TYPE OF DUPLEXER PROVIDES LITTLE REJECTION OF OUT OF BAND SIGNALS

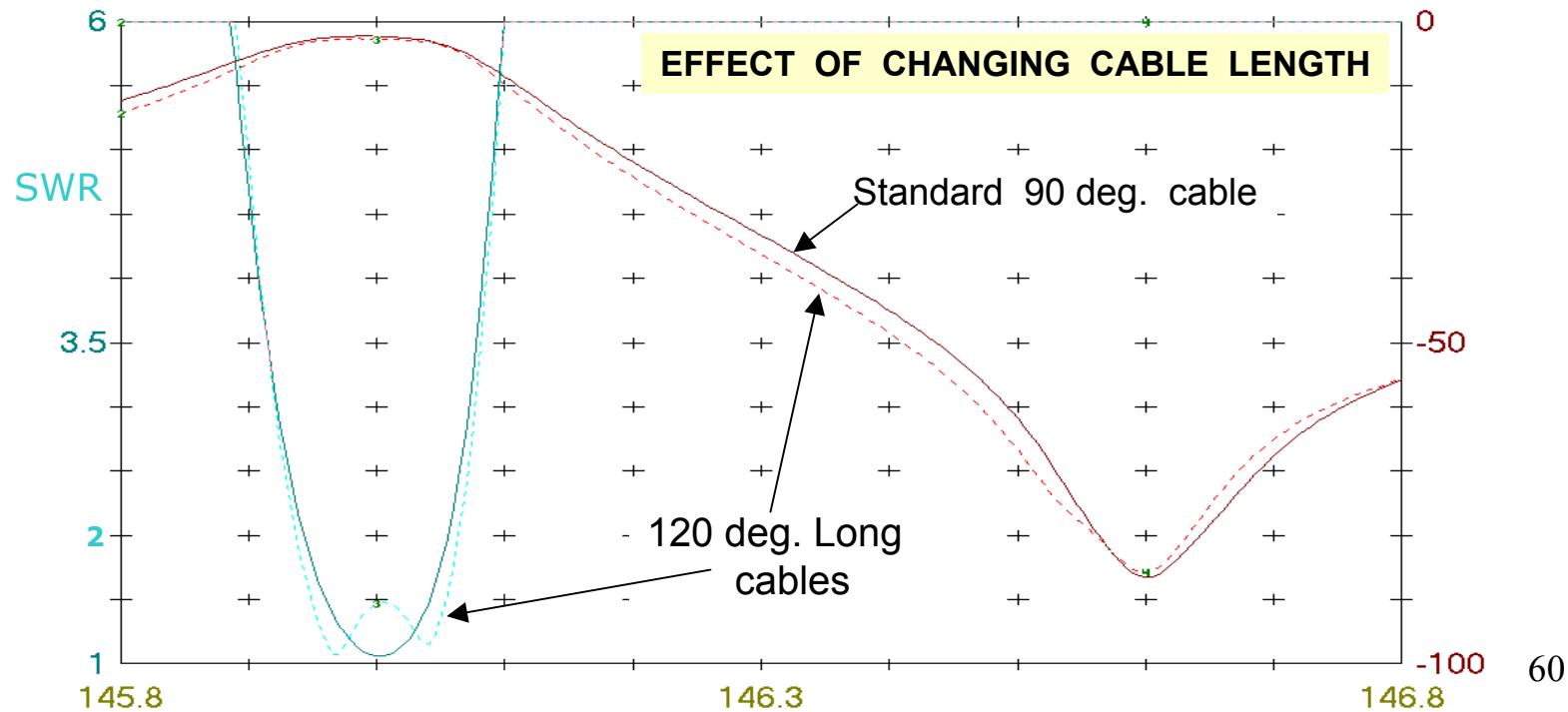


- ❑ ADJUSTING THE BANDPASS FREQUENCY FOR MINIMUM SWR IS BEST
- ❑ MAY REQUIRE ABILITY TO READ LOW SWR VALUES



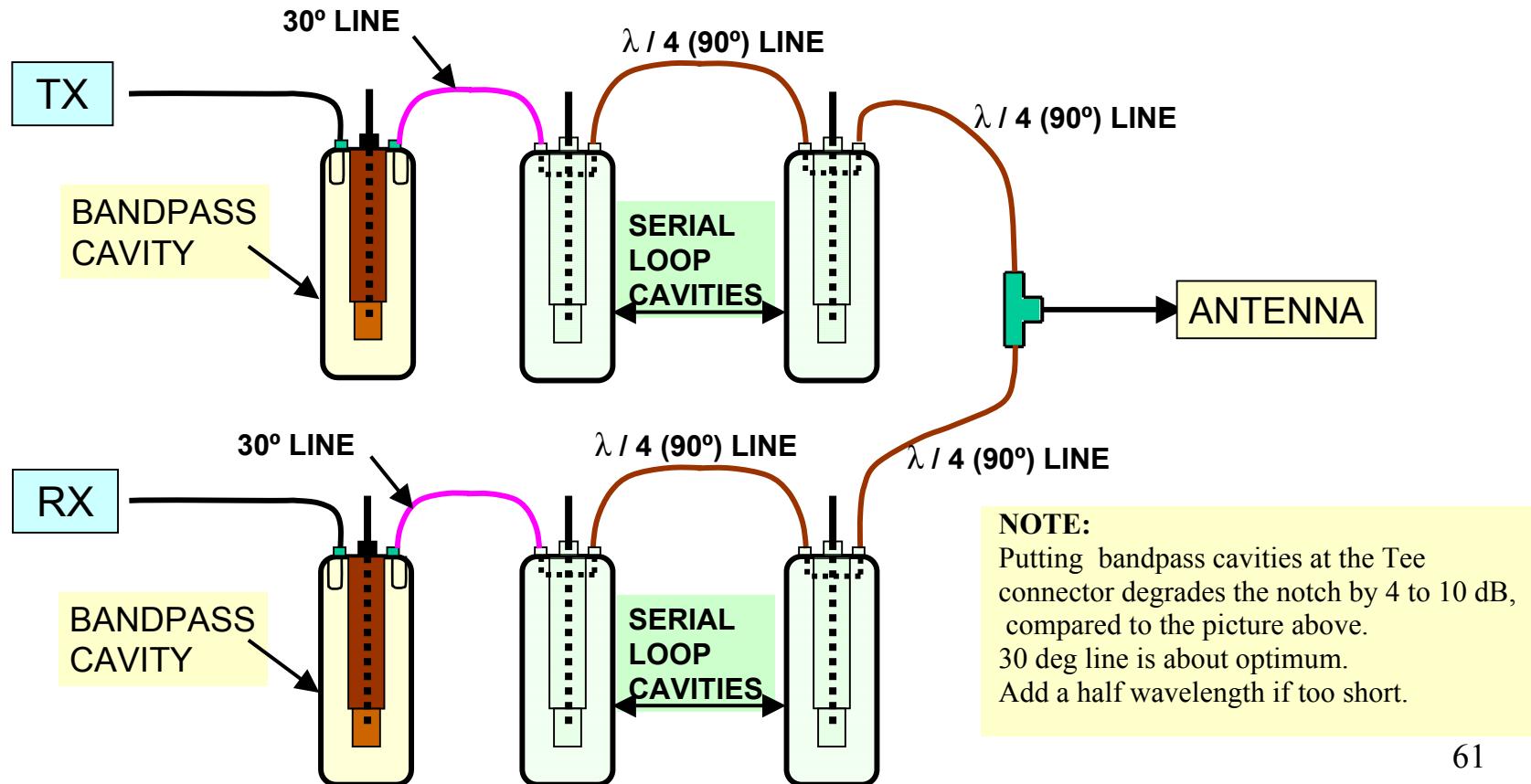
EXAMPLE OF DUPLEXER BUILT WITH FOUR 6 in. SERIAL LOOP CAVITIES

- THE $\lambda/4$ CABLES AT THE TEE JUNCTION HAVE BEEN INCREASED IN LENGTH 33%
- SLIGHT CHANGE IN RESPONSE
- SWR CURVE HAS RIPPLES NOW. THIS MAY BE USED TO CHECK FOR PROPER CABLE LENGTHS



EXAMPLE OF DUPLEXER BUILT WITH (2) BANDPASS + (4) SERIAL LOOP NOTCH BANDPASS CAVITIES

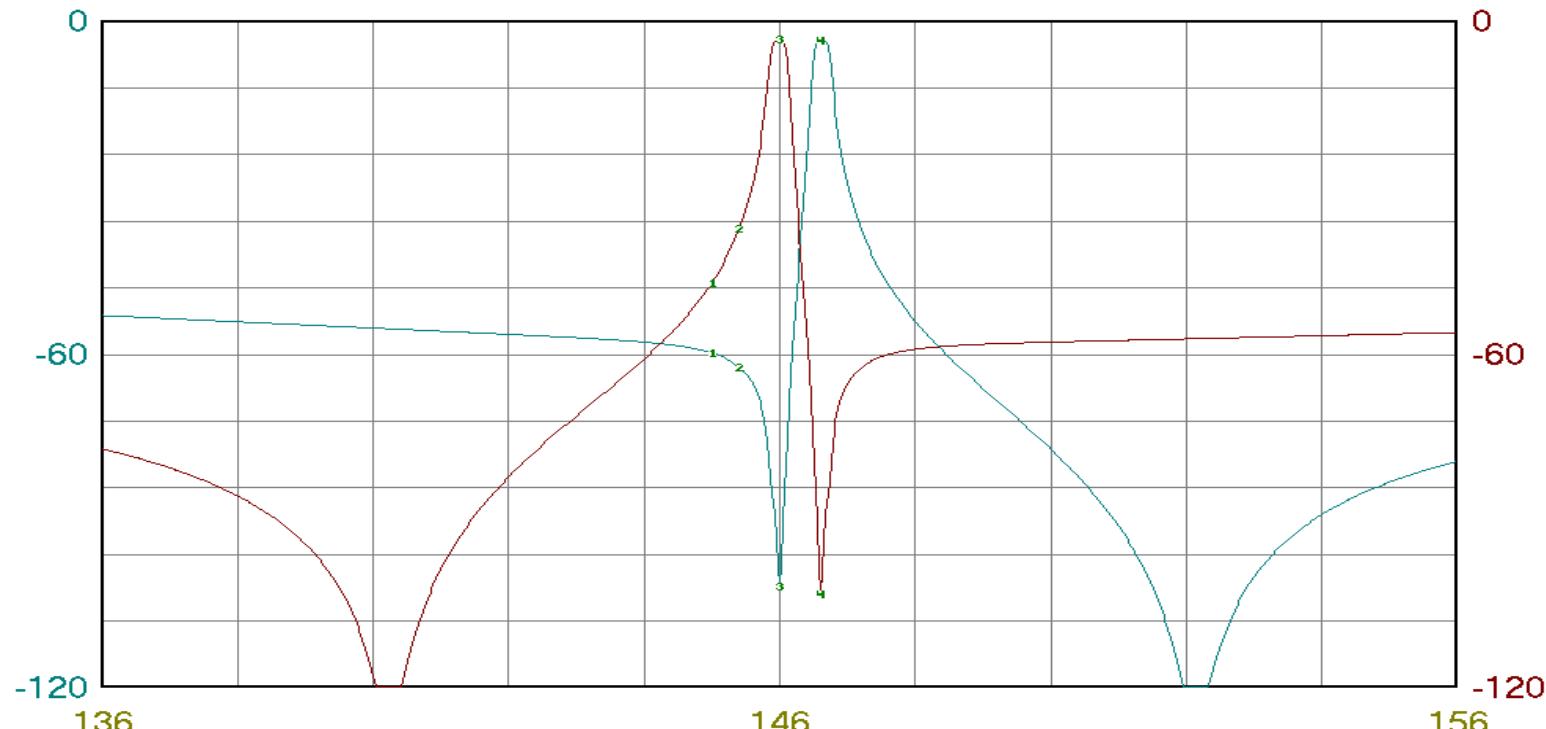
- BANDPASS CAVITIES SHOULD BE PLACED AHEAD OF SERIAL LOOP CAVITIES
- THE 30° LINE AFTER THE BANDPASS CAVITIES ADDS ~5dB NOTCH DEPTH
(Two Loop Notch Bandpass cavities require different cable lengths)
- IMPROVES REJECTION AWAY FROM THE NOTCH – BANDPASS FREQUENCIES



EXAMPLE OF DUPLEXER BUILT WITH TWO BANDPASS + FOUR SERIAL LOOP CAVITIES

FEATURES:

- 3 dB BANDPASS LOSS (~ 1dB per cavity)
- ~102 dB NOTCH
- EXCELLENT REJECTION OF OUT OF BAND SIGNALS



COMPLETE DUPLEXER RESPONSE OVER A 20 MHz FREQ SPAN

Calculating the Cable Lengths

$$L := \text{deg} \cdot 32.785 \cdot \frac{Vf}{f}$$

Where:

L = length in inches. This is the overall length from
- The connector base to connector base
- From connector base to the center of the Tee (if used)

Deg = electrical degrees as req'd from previous slides

If the calculated length is too short add 180 degrees
or an integer multiple.

Vf = Coax velocity factor

f = mid frequency in MHz
= average frequency of the bandpass and notch frequencies.

Example:

With $Vf = 0.67$ $f = 220$ MHz $\text{deg} = 28.5$

Gives:

$L = 2.845$ inch ... which is probably too short !

We can add any integer multiple of a half wavelength (180 deg.) to the cable

We recalculate using $\text{deg} = 28.5 + 180 = 208.5$

Gives $L = 20.82$ in. ... much better !

PITFALLS

- ❑ AVOID LOW QUALITY CONNECTORS
SPECIALLY TEES.

The picture on the right shows an N type connector that uses a steel spring for making contact with the thru line. The added inductance was calculated from return loss measurement at 100 MHz (9.5 dB) and 1 GHz (5 dB) with both female ends terminated (50 ohms). This gave ~ 7 nH inductance. Therefore a 100 nH loop will have its inductance increased by 7%, thus lowering its resonant frequency 3.5% or ~ 5 MHz at 146 MHz !



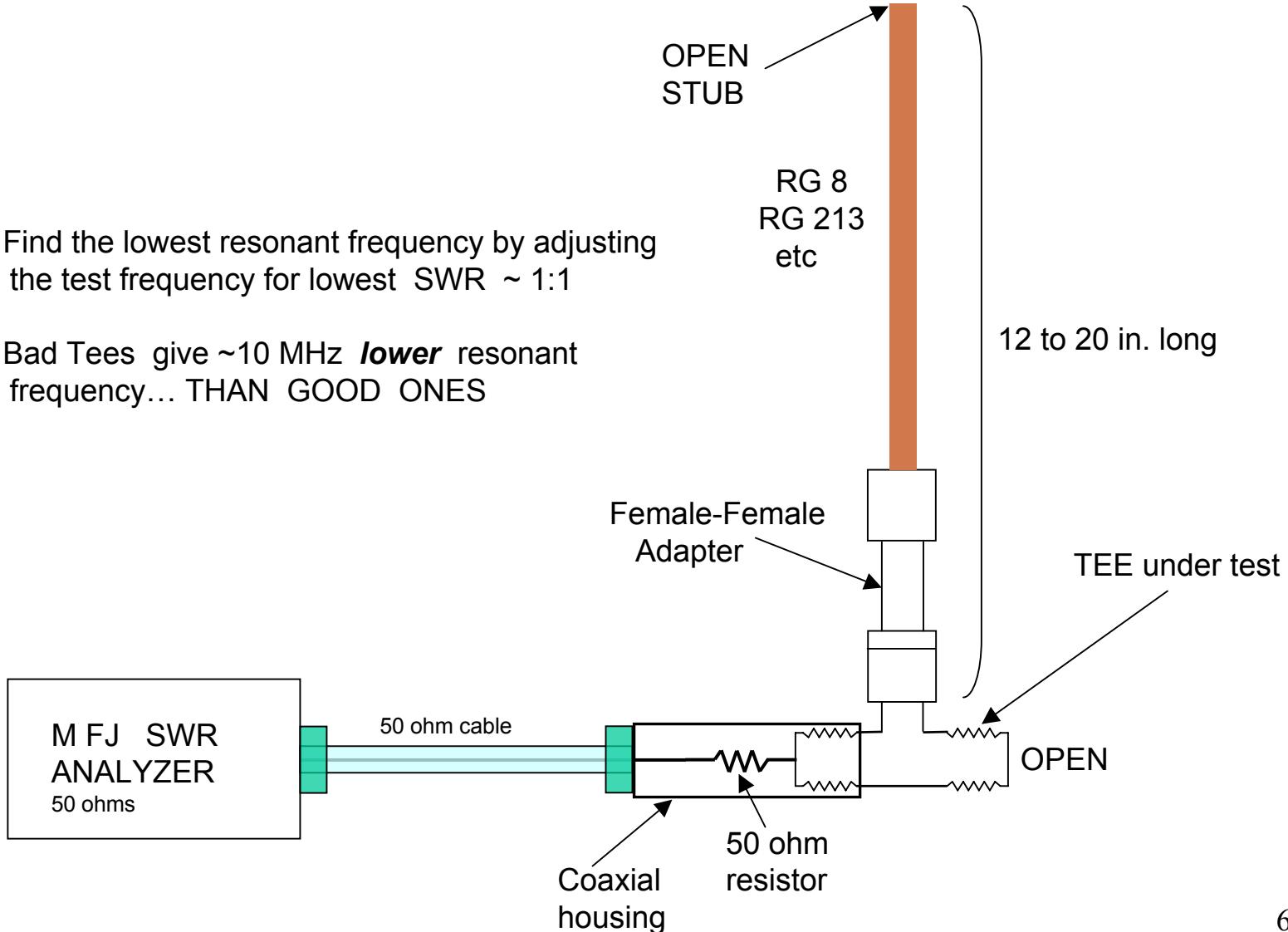
N Type Tee

- ❑ USE SILVER PLATED CONNECTORS
- ❑ UNPLATED COPPER CAVITIES MAY BE
POLISHED AND CLEANED WITH
“BRASSO” (liquid copper / brass cleaner)
LEAVES A PROTECTIVE FILM
- ❑ SLIDING CONTACTS MAY BE LUBRICATED
WITH SILICONE CLEANER OR VASELINE
- ❑ TERMINATE THE “UNUSED” PORT WHEN
TESTING FOR LOSS OR SWR

CENTER CONNECTOR
USES A SPRING FOR
CONTACT !

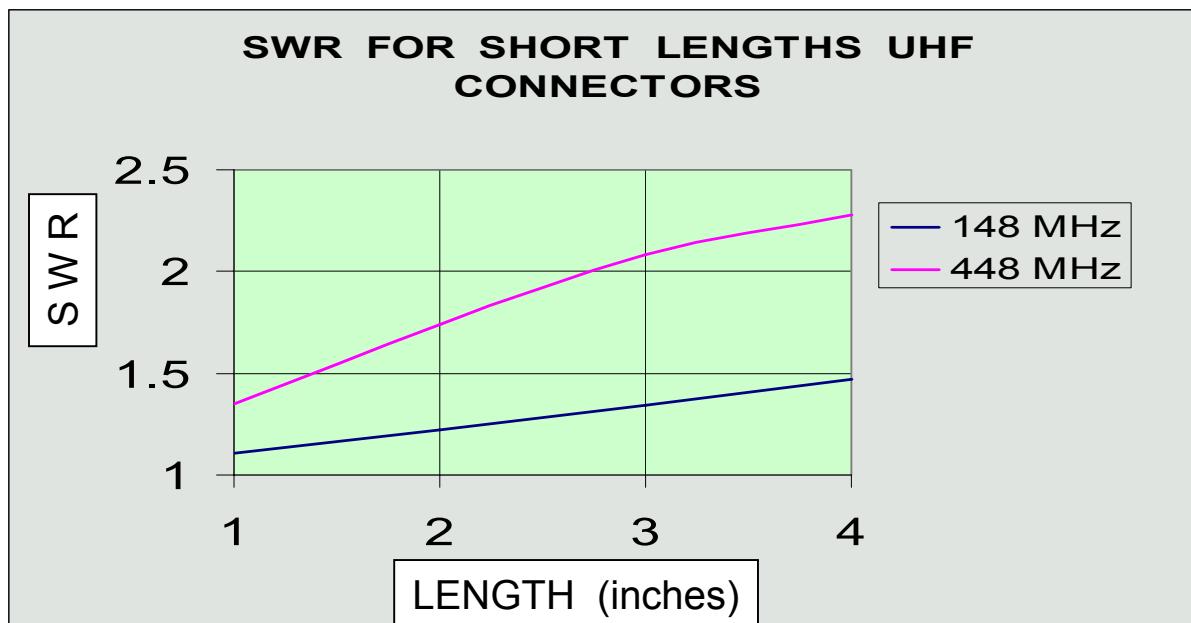
TEE CONNECTOR TEST SET-UP

- Find the lowest resonant frequency by adjusting the test frequency for lowest SWR $\sim 1:1$
- Bad Tees give ~ 10 MHz *lower* resonant frequency... THAN GOOD ONES



PITFALLS

- ❑ TEMPERATURE SENSITIVITY:
UNCOMPENSATED Cu RESONATORS WILL SHOW
A TEMPERATURE COEFFICIENT OF ~ -1.3 KHz / degC (146 MHz)
- ❑ DOUBLE SHIELD CABLES AND N TYPE CONNECTORS PREFERRED
- ❑ AVOID – IF POSSIBLE - UHF ADAPTERS
THEIR IMPEDANCE IS BELOW 50 OHMS: ~33 OHMS
THEY WILL LIKELY INCREASE THE SWR See: <http://www.qsl.net/vk3jeg/pl259tst.html>



CONCLUSION

- ❑ THIS PRESENTATION COVERS THE MOST IMPORTANT DUPLEXER ELEMENTS:
BANDPASS + 4 TYPES OF NOTCH – BANDPASS + NOTCH DESIGNS
- ❑ SIMULATION SOFTWARE WITH REAL TIME TUNING CAPABILITIES ALLOWS « BREADBOARDING » DUPLEXERS
- ❑ LEARN TUNING, CHECK FOR SENSITIVITY TO COMPONENT VARIATIONS SUCH AS Q FACTOR, CABLE LENGTHS ETC.

REFERENCES

- ❑ Repeater Builder Website: <http://www.repeater-builder.com/rbtip/>
- ❑ LINEAR SIMULATION SOFTWARE:
SuperStar from Eagleware - now Agilent (used here)
Designer SV for Windows from Ansoft (free) <http://www.ansoft.com/downloads.cfm>
LT Spice / Switcher CAD (free) <http://www.linear.com/company/software.jsp>
- ❑ Duplexer Theory and Testing by Dave Metz WA0UAQ (.pdf format)
- ❑ KI7DX 6 Meter Repeater http://www.wa7x.com/ki7dx_rpt.html
- ❑ 6 Meter Heliax Duplexers <http://www.dallas.net/~jvpoll/dup6m/dup6m.html>
- ❑ Duplexers: theory and tune up <http://www.seits.org/duplexer/duplexer.htm>
- ❑ Upgrading Boonton Models 92/42 RF Voltmeters Jacques Audet
Communications Quarterly Spring 97
- ❑ THANKS to Jean-Nicol VE2BPD for the photos and the bad tee
- ❑ THANKS to Bob G3VVT for reporting the reversed notch location in double loop cavities.